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Executive Summary

This report by the Ministry of the Environment (Ministry) examines actions that have been taken to restore and secure Walkerton's water supply, and bring it into compliance with the *Ontario Drinking Water Standards*.

It reports on actions taken by the Municipality of Brockton (Municipality) and the Walkerton Public Utilities Commission (PUC) including their response to Field Orders issued by the Ministry. These actions included steps taken to restore the potability of the water supply and steps taken to prevent a recurrence of contamination.

It outlines additional actions taken by the Ministry to audit and confirm restoration activities that were completed to comply with Ministry Orders.

The report provides an assessment of these actions, including the following overall conclusions:

- reports from the PUC, prepared by the Ontario Clean Water Agency and GAP EnviroMicrobial Services Inc., support the conclusion that restoration activities have eliminated the contamination from the water distribution system and from individual buildings and residences in Walkerton;

- analysis undertaken by the Ministry through its extensive audit and sampling programs confirms that the water distribution system and individual buildings and residences have been disinfected;

- Well 5 should be permanently plugged and abandoned. Further treatment is required at Well 6 as there is a potential for direct access of surface water into the well. The groundwater supply at this well may also be under the direct influence of surface water. While Well 7 exhibits the best raw water quality, there is some hydraulic connection with Well 6. Further treatment is therefore required;

- implementation of the filtration and chlorination treatment system for Wells 6 and 7 will provide an effective double treatment barrier to secure the water supply. Ministry sampling has confirmed the system's effectiveness in delivering water that meets the *Ontario Drinking*

Water Standards;

- system upgrades and operating procedures that have been put in place will provide additional safeguards for the security of the water supply system, and;

- implementation of the requirements regarding Walkerton's water wells in this report will provide for the continuing security of the water supply system.

Based on all of the information provided to the Ministry, and the results of its audit and sampling programs, the Ministry of the Environment is satisfied that, with the exception of hardness (an operational guideline), the Walkerton water supply system is now in compliance with the *Ontario Drinking Water Standards*.

CONCLUSIONS

This report examines the actions taken by the Municipality and the PUC to restore and secure the Walkerton water supply and distribution system after the May/June 2000 outbreak of gastroenteritis in the Walkerton area, caused by *E. coli* O157:H7 and *Campylobacter* bacteria.

As a result of the outbreak, the Medical Officer of Health for Bruce-Grey-Owen Sound issued a Boil Water Advisory for Walkerton residents on May 21, 2000. The next day the Ministry was asked to investigate the operation and security of the water system.

On May 25, 2000, the Ministry issued its first in a series of orders to the Municipality and the PUC setting out the actions necessary to restore and secure the Walkerton water supply system. The Bruce-Grey-Owen Sound Health Unit's epidemiological report on the outbreak showed that contamination was widespread throughout the municipal water distribution system, confirming the need for the extensive remediation program that has been undertaken in Walkerton.

The following outlines the final conclusions of the Ministry's report:

Restoring the Distribution System

The program to clean and disinfect the distribution system was completed by OCWA and its agents, on behalf of the Municipality and the PUC. OCWA reported that:

- the water distribution system was completely flushed, effectively removing bacteria and loose sediment from the system;
- Walkerton's two water storage facilities (standpipes) were completely cleaned and disinfected, addressing any concerns with bacteria in the standpipes;
- dead end locations which might have remained contaminated if left unchecked were identified, fitted with fire hydrants, or blow off lines and flushed, or disinfected during the building-by-building disinfection process;
- thirty-one kilometres of large diameter pipes were swabbed a

minimum of four times, effectively removing and reducing accumulated biofilm from these pipes;

- the plumbing in each of the 1,816 separate buildings in Walkerton was disinfected, including traditional plumbing fixtures, appliances and other systems that made use of the municipal water supply;
- five kilometres of 100 mm watermains, which could not be swabbed because of a build-up of oxidation and hard water scale were replaced; and
- an extensive water sampling and testing program was undertaken to confirm the effectiveness of the disinfection and restoration activities.

In order to confirm the effectiveness of OCWA's disinfection and restoration program, the Ministry completed extensive audit and sampling programs, resulting in the testing of over 5,000 water samples.

These audit and sampling programs included:

- a Disinfection Audit to determine the effectiveness of OCWA's building-by-building disinfection program, based on 683 samples,
- a Building-by-Building Sampling Program to confirm that the plumbing in every home and business in Walkerton was disinfected, based on 2,607 samples;
- a Post-Restoration Sampling Program to test Walkerton's water quality upon the completion of OCWA's summer restoration work (including the pipe replacement program) based on 698 samples; and
- a distribution system sampling program to audit and confirm OCWA's sampling results and to monitor the ongoing microbiological quality of the water supply system.

Based on the results of the Ministry's audit and sampling programs, the Ministry concludes that:

- **OCWA's restoration program was successful in disinfecting the distribution system and the plumbing in all buildings and residences of Walkerton, resulting in the elimination of any pathogens, including *E. coli* O157:H7, *Salmonella* and *Campylobacter* bacteria;**
- **the water in the distribution system meets all bacteriological parameters defined in the *Ontario Drinking Water Standards*.**

The Security of Walkerton's Water Supply

Actions taken to secure the water supply focussed on the integrity of Walkerton's wells, upgrades to the PUC's operational procedures and monitoring equipment, the elimination of cross-connections to the municipal water supply and the implementation of filtration and chlorination treatment for Wells 6 and 7.

The Elimination of Cross-Connections

OCWA reported that all cisterns (474) and 39 properties with private wells were examined and disconnected, as required, from the municipal water supply system as part of its extensive cross-connection elimination program.

OCWA's results and conclusions are consistent with Ministry field observations and audit on cross-connections gathered through the Ministry's Building-by-Building Sampling Program. All known cross-connections between private water systems and the municipal distribution system have been eliminated.

The Ministry is satisfied with OCWA's conclusion that the cross-connection elimination program was successful in removing the risk of cross-connection contamination of the municipal water supply, adding to the security of the system. Ongoing municipal public education and enforcement of the PUC's by-law banning residential cross-connections will be essential.

Operational Procedures and Monitoring Equipment

OCWA has undertaken an extensive program of upgrades to the water supply system, including the installation of continuous chlorine and turbidity analysers and monitoring and alarm systems that report on system activity.

OCWA also developed a series of standard operating procedures to deal with equipment operation, sampling requirements for both chemical (chlorine) and bacteriological analyses, and contingency plans for operations and adverse sampling results.

The Ministry is satisfied that the upgrades to the monitoring equipment and

operational procedures of the Walkerton water supply system provide safeguards for the security of the water supply.

Wells 1, 2 and 3

Un-maintained former production wells represent a threat to the security of an aquifer. Improperly sealed casings and/or casing penetrations represent a direct route for surface water access to the water supply aquifers.

In order to ensure that these wells are secured, the Ministry will require that Wells 1 and 2 be plugged and abandoned. Well 3 has been disconnected from the distribution system pending a decision on its future use as part of the RVA study.

Well 5

Well 5 was taken out of production on May 23, 2000. On June 9, 2000, the Ministry issued an Order to the Municipality requiring that Well 5 remain closed and disconnected from the Walkerton water supply system. The Ministry will require that Well 5 be permanently abandoned and plugged.

Well 6

The Ministry concludes that there is a potential for direct access of surface water into the well and that the groundwater supply for this well may be under the direct influence of surface water.

The implementation of filtration and chlorination treatment at Well 6 is required to bring the system into compliance with the *Ontario Drinking Water Standards* and Procedure B13-3, *The Chlorination of Potable Water Supplies in Ontario.*

Longer-term rehabilitation will require repairs to, and possible further capacity development of, Well 6 and adjacent test wells, the filling of an adjacent pond and a well head protection program.

Well 7

Well 7 exhibits the best raw water quality, both microbiologically and chemically, of the Walkerton wells. Based on findings of some hydraulic connection between Wells 6 and 7, the implementation of the filtration and chlorination treatment at Well 7 is also necessary. A municipal well head protection program will also be required.

Repairs to the well, including the removal of the existing overflow pipe and repairs to adjacent test well TW1-86 will be required to further protect Well 7 as a secure source of groundwater. Further capacity development in the Well 7 area will also be examined as part of the R. V. Anderson study.

Interim Filtration Treatment for Wells 6 and 7

The implementation of the filtration and chlorination treatment system for Wells 6 and 7 will provide an effective double treatment barrier to secure the water supply. Ministry sampling has confirmed the system's effectiveness in delivering water that meets the *Ontario Drinking Water Standards.*

Chemical Characterization

Finally, the Ministry's chemical characterization of Walkerton's water supply, compared to the parameters set out in the *Ontario Drinking Water Standards*, clearly shows that the water quality meets all *Ontario Drinking Water Standards* parameters, with the exception of hardness, an operational guideline.

Summary

In summary, based upon the information received pursuant to Ministry Orders and the Ministry's own monitoring data, the Ministry is satisfied that the restoration work carried out in Walkerton has brought the water supply system into compliance with the *Ontario Drinking Water Standards.*

The Ministry will continue its work with the Municipality of Brockton and the Walkerton Public Utilities Commission to ensure the implementation of the follow-up actions identified in the report.

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Sommaire

Le présent rapport du ministère de l'Environnement décrit les mesures qui ont été prises pour assainir le réseau de distribution d'eau de Walkerton et en garantir la conformité avec les *normes de qualité de l'eau de l'Ontario*.

Y sont décrites les mesures qu'ont prises la municipalité de Brockton et la commission des services publics de Walkerton, dont les mesures prescrites conformément aux arrêtés que le ministère a pris à leur endroit. Entre autres mesures, la municipalité et la commission devaient rétablir la qualité hygiénique de l'eau distribuée à la population et prévenir toute récurrence de la contamination.

Le rapport décrit en outre les mesures que le ministère a prises pour établir si les travaux prescrits conformément aux arrêtés ont bel et bien été effectués.

Enfin, le rapport porte un jugement sur les mesures qui ont été prises et présente des conclusions générales.

Conclusions générales

- Les rapports de la commission (rédigés par l'Agence ontarienne des eaux et la société GAP EnviroMicrobial Services Inc.) appuient la conclusion suivante : les travaux d'assainissement ont éliminé la contamination qui était présente dans le réseau de distribution d'eau, les bâtiments et les habitations de Walkerton.

- Les nombreuses analyses d'eau que le ministère a effectuées conformément à son vaste programme de vérification-échantillonnage confirment que le réseau de distribution d'eau et la tuyauterie des bâtiments et des habitations ont été désinfectés.

- Le puits n° 5 doit être bouché en permanence et mis hors service. Le puits n° 6 nécessite des travaux supplémentaires, car il est possible que des eaux de surface puissent s'y introduire. En outre, les eaux souterraines associées au puits n° 6 pourraient entrer en contact avec des eaux de surface. L'eau brute de la meilleure qualité provient du puits n° 7, mais ce puits est relié par voie hydraulique au puits n° 6. Il nécessite donc des travaux supplémentaires.

- Les dispositifs de filtration et de chloration dont sont dotés les puits n^{os} 6

et 7 offrent une double protection contre les bactéries. Les échantillons d'eau que le ministère a prélevés confirment l'efficacité du traitement : l'eau potable satisfait aux *normes de qualité de l'eau de l'Ontario*.

- La modernisation des dispositifs et des modes de traitement offrira une protection supplémentaire contre les bactéries.

- Les prescriptions formulées plus bas en ce qui concerne l'entretien des puits de Walkerton garantiront la qualité de l'eau distribuée à la population.

D'après les renseignements qu'on lui a fournis et les résultats de son programme d'échantillonnage, le ministère estime que l'eau du réseau de distribution de Walkerton est conforme aux *normes de qualité de l'eau de l'Ontario*, sauf en ce qui concerne la dureté de l'eau (un paramètre se rapportant aux méthodes de travail).

CONCLUSIONS

Le présent rapport décrit les mesures que la municipalité et la commission ont prises pour assainir le réseau de distribution d'eau de Walkerton après l'épidémie de gastro-entérite qui a sévi dans la région de Walkerton en mai et en juin 2000, l'épidémie ayant été causée par les bactéries *E. coli* O157:H7 et *Campylobacter*.

Le médecin hygiéniste de Bruce-Grey-Owen Sound a prescrit à la population, le 21 mai 2000, de faire bouillir l'eau du robinet. Le jour suivant, il a demandé au ministère d'examiner le réseau de distribution d'eau et de faire une enquête.

Le 25 mai 2000, le ministère a pris un premier arrêté à l'endroit de la municipalité et de la commission des services publics. L'arrêté prescrit les mesures que la municipalité et la commission devaient prendre pour assainir le réseau de distribution d'eau de Walkerton et le remettre en service. Le Bureau de santé de Bruce-Grey-Owen Sound a fait observer, dans son rapport épidémiologique, que la contamination s'étendait à tout le réseau de distribution, d'où la nécessité du vaste programme d'assainissement mis en oeuvre à Walkerton.

Sont données plus bas les conclusions définitives du ministère.

Assainissement du réseau de distribution d'eau

Les travaux de nettoyage et de désinfection ont été réalisés par l'Agence ontarienne des eaux et ses agents, au nom de la municipalité et de la commission des services publics. L'Agence a fait le rapport suivant :

- On a entièrement vidangé le réseau de distribution d'eau, ce qui a permis d'en chasser les bactéries et les sédiments meubles.
- On a complètement nettoyé et désinfecté les deux réservoirs d'eau (des tuyaux verticaux) afin d'y détruire les bactéries qui auraient pu y être présentes.
- On a relevé l'emplacement des conduites en cul-de-sac où les bactéries auraient pu persister. On les a reliées à un poteau d'incendie ou à une conduite de purge pour chasser l'eau qu'elles contenaient, ou on les a désinfectées pendant les travaux de désinfection de la tuyauterie des bâtiments et des habitations de Walkerton.
- On a curé au moins quatre fois les conduites d'un large diamètre (représentant une longueur totale de 31 kilomètres), ce qui a délogé le film biologique qui s'était accumulé sur les parois.
- On a désinfecté la tuyauterie des 1 816 bâtiments et habitations de

Walkerton, y compris les appareils sanitaires ordinaires et les appareils qui utilisent l'eau du réseau de distribution municipal.

- On a remplacé, sur cinq kilomètres, des conduites d'un diamètre de 100 mm qu'on ne pouvait pas curer en raison de la forte accumulation d'écailles d'eau dure et de rouille.
- On a entrepris un vaste programme d'échantillonnage et d'analyse pour confirmer le succès des travaux de désinfection et de remise en état du réseau.

Afin de confirmer le succès des travaux de désinfection et de remise en état du réseau, le ministère a prélevé de nombreux échantillons d'eau partout dans le réseau et a analysé au moins 5 000 échantillons.

Mesures prises conformément au programme de vérification-échantillonnage :

- Le ministère a prélevé 683 échantillons d'eau pour déterminer si la tuyauterie de chaque bâtiment de Walkerton était désinfectée après les travaux de l'Agence ontarienne des eaux.
- Il a prélevé 2 607 échantillons d'eau pour déterminer si la tuyauterie de chaque habitation et de chaque entreprise de Walkerton était désinfectée.
- Il a prélevé 698 échantillons d'eau pour déterminer la qualité de l'eau de Walkerton après l'achèvement des travaux de remise en état du réseau que l'Agence avait effectués pendant l'été (ce qui comprend le remplacement des conduites que l'on ne pouvait pas curer et assainir).
- Le ministère prélève des échantillons d'eau un peu partout dans le réseau de distribution pour vérifier les résultats d'échantillonnage de l'Agence et surveiller la qualité microbiologique de l'eau au sein du réseau de distribution.

Voici les conclusions auxquelles le ministère est arrivé d'après son programme de vérification-échantillonnage :

- **L'Agence ontarienne des eaux a désinfecté avec succès le réseau de distribution d'eau et la tuyauterie de chaque bâtiment et de chaque habitation de Walkerton. Les agents pathogènes, dont les bactéries *E. coli* O157:H7, *Salmonella* et *Campylobacter*, ont bel et bien été éliminés.**
- **L'eau du réseau de distribution satisfait à tous les paramètres bactériologiques que définissent les *normes de qualité de l'eau de l'Ontario*.**

Qualité hygiénique de l'eau de Walkerton

Les mesures prises pour garantir une eau potable hygiénique ont principalement porté sur quatre choses : l'intégrité structurale des puits de Walkerton; la modernisation des méthodes de travail et des appareils de surveillance qu'emploie la commission des services publics; l'élimination des branchements entre des installations d'eau privées et le réseau de distribution d'eau de Walkerton; des traitements de filtration et de chloration aux puits n^{os} 6 et 7.

Élimination des branchements irréguliers

L'Agence ontarienne des eaux a examiné toutes les citernes (474) et 39 puits privés, et les a séparés des conduites du réseau de distribution municipal.

Les conclusions auxquelles l'Agence est arrivée concordent avec les observations de terrain du ministère et les résultats du programme de vérification-échantillonnage « bâtiment par bâtiment ». Tous les embranchements entre des installations d'eau privées et le réseau de distribution d'eau de Walkerton ont été éliminés.

Le ministère accepte les conclusions de l'Agence : l'élimination des branchements irréguliers a supprimé le risque de contamination du réseau par l'introduction d'eau polluée provenant d'une canalisation privée. Il est essentiel de continuer à informer la population et à faire observer le règlement municipal interdisant le branchement d'une canalisation privée à une conduite du réseau de distribution d'eau.

Méthodes de travail et appareils de surveillance

L'Agence ontarienne des eaux a apporté toutes sortes d'améliorations au réseau de distribution d'eau. Elle a installé entre autres un appareil analysant continuellement la teneur en chlore, un appareil de mesure de la turbidité de l'eau, un système de surveillance automatisée et un système d'alarme en cas de panne.

L'Agence a aussi défini les méthodes de travail à observer relativement à l'utilisation des appareils, au prélèvement d'échantillons subissant des analyses chimiques (teneur en chlore) et bactériologiques, et aux plans d'intervention d'urgence en cas de panne du matériel ou d'une eau non conforme aux normes prescrites.

Le ministère estime que la modernisation des appareils de surveillance et des méthodes de travail offre une bonne protection contre la pollution de l'eau du réseau.

Puits n^{os} 1, 2 et 3

Les anciens puits non entretenus peuvent faire introduire des eaux polluées dans la nappe aquifère. Des raccords mal calfeutrés, un tubage fissuré, etc. peuvent en effet laisser entrer des eaux de surface.

Par conséquent, le ministère obligera la municipalité à boucher les puits n^{os} 1 et 2, et à les mettre hors service. Le puits n° 3 a été débranché du réseau de distribution d'eau. Son utilisation future sera décidée lorsque l'étude R.V. Anderson sera terminée.

Puits n° 5

Le puits n° 5 a été mis hors service le 23 mai 2000. Le ministère a pris un arrêté, le 9 juin 2000, obligeant la municipalité à débrancher le puits n° 5 du réseau de distribution d'eau de Walkerton. Il obligera la municipalité à boucher le puits et à le mettre hors service en permanence.

Puits n° 6

Le ministère croit que des eaux de surface risquent de s'introduire dans le puits et qu'il pourrait fort bien y avoir un contact entre des eaux de surface et les eaux souterraines.

Pour que les installations du puits n° 6 soient conformes aux *normes de qualité de l'eau de l'Ontario* et à la directive B13-3 (*chloration de l'eau potable en Ontario*), il faut absolument que l'eau provenant du puits n° 6 subisse une filtration et une chloration.

Le puits n° 6 et les puits d'essai adjacents nécessiteront également des réparations. Il pourrait en outre être nécessaire d'accroître leur débit de production, de remblayer l'étang situé à proximité du puits n° 6 et, enfin, d'établir un programme de protection des têtes de puits.

Puits n° 7

De tous les puits de Walkerton, le puits n° 7 renferme l'eau brute de la meilleure

qualité, tant sur le plan chimique que microbiologique. Étant donné que l'on a relevé une liaison par voie hydraulique entre les puits nos 6 et 7, il sera nécessaire de faire subir une filtration et une chloration à l'eau du puits n° 7. Il faudra aussi mettre en oeuvre un programme de protection des têtes de puits.

Afin de protéger davantage les eaux du puits n° 7, il faudra réparer le puits et enlever le tuyau d'évacuation du trop-plein. Il faudra aussi réparer le puits d'essai TW1-86 qui se trouve près du puits n° 7. L'étude R.V. Anderson établira aussi s'il faudrait accroître le débit de production du puits n° 7.

Filtration et chloration de l'eau des puits nos 6 et 7

La filtration et la chloration de l'eau puisée aux puits nos 6 et 7 offriront une double protection contre les bactéries. Le ministère a confirmé l'efficacité des appareils de filtration et de chloration. L'eau puisée aux puits nos 6 et 7 satisfait aux *normes de qualité de l'eau de l'Ontario*.

Caractérisation chimique

Le ministère a déterminé les caractéristiques chimiques de l'eau du réseau de distribution de Walkerton. La caractérisation chimique de l'eau montre clairement que l'eau traitée satisfait aux paramètres que définissent les *normes de qualité de l'eau de l'Ontario*, sauf en ce qui concerne la dureté de l'eau, un paramètre associé aux méthodes de travail.

Sommaire

En résumé, d'après les renseignements obtenus conformément aux arrêtés pris à l'endroit de la municipalité et de la commission des services publics, et d'après ses propres données de surveillance, le ministère de l'Environnement est persuadé que les travaux entrepris à Walkerton ont réussi à rendre le réseau de distribution d'eau conforme aux *normes de qualité de l'eau de l'Ontario*.

Le ministère continuera de travailler avec la municipalité de Brockton et la commission des services publics de Walkerton pour que soient prises les mesures de suivi mentionnées dans le présent rapport.

Ontario Clean Water Agency
Agence Ontarienne Des Eaux

The Ontario Clean Water Agency's Report to the Walkerton Public Utilities Commission on the Operational Measures Taken to Address the E. Coli Water Contamination in the Town of Walkerton

Rec'd. by K West Oct. 23/00

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October 20, 2000

Mr. Phillip Bye
District Supervisor
Owen Sound District Office
Ministry of the Environment
1580 20th Street East
P.O. Box 967
OWEN SOUND ON N4K 6H6

Dear Mr. Bye:

Re: Municipality of Brockton
OCWA Water System Remediation Report

Please find enclosed, a copy of the above noted report. As noted in the covering letter for the report, this report was carried out by OCWA to the Walkerton PUC. This report should be included as fulfilling part of the requirements for the Municipality of Brockton of Section 10 of the Field Order of May 25, 2000.

Yours very truly,

MILLER THOMSON LLP

John L. Martin

cc: R. Radford
S. Burns

Ontario Clean Water Agency
Agence Ontarienne Des Eaux

October 17, 2000

Mr. Jim Kieffer
Chair
Walkerton Public Utilities Commission
4 Park Street
Box 220
Walkerton, ON
N0G 2V0

Dear Mr. Kieffer,

Re: Municipality of Brockton (Walkerton)
Remediation of Municipal Water Supply and Distribution System

Please find attached the Ontario Clean Water Agency's (OCWA's) report to the Walkerton Public Utilities Commission on the operational measures taken to address the escherichia coli (e. coli) O157:H7 water contamination in the Town of Walkerton in late May 2000.

The purpose of this report is to outline OCWA's efforts on behalf of the Walkerton Public Utilities Commission to restore the integrity of Walkerton's water distribution system following the e. coli outbreak.

The report describes operational activities including, but not limited to, the installation of instrumentation and monitoring equipment, the flushing and swabbing of the water distribution system, a comprehensive building-to-building disinfection program, the establishment of extensive sampling procedures, the replacement of approximately five kilometres of watermains in Walkerton and the development of a strategy aimed at ensuring long-term security of the water supply.

It is intended that the information contained within this report contribute to the body of knowledge required by the Medical Officer of Health for the ultimate lifting of the Boil Water Advisory in the Town of Walkerton in the Municipality of Brockton.

.../2

In the event you have any questions regarding the contents of this report, please feel free to contact me directly at (416) 314-0757.

Sincerely,

Paul Scott
President and CEO

c: Stindar K. Lal ✓
Deputy Minister
Ministry of Environment

Dan Atkinson
Vice President, Central and Western Area (Acting)
OCWA

Ontario Clean Water Agency
Agence Ontarienne Des Eaux

The Ontario Clean Water Agency's Report to the Walkerton Public Utilities Commission on the Operational Measures Taken to Address the *E. coli* Water Contamination in the Town of Walkerton.

October 17, 2000

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ACKNOWLEDGMENTS

The employees of the Ontario Clean Water Agency (OCWA) would like to extend their sympathies to the residents of the Town of Walkerton, Ontario, and to salute their courage and perseverance following the *E. coli* water contamination crisis that began in their community in the spring of 2000.

The remediation effort in Walkerton has been large in its scope, comprising teams of volunteers, experts, contractors and municipal and provincial government officials. OCWA would like to acknowledge the citizens of Walkerton for allowing us to play a key role in this process.

OCWA extends special thanks to:

- GAP EnviroMicrobial Services Inc. for their expert knowledge and support throughout the remediation process in Walkerton.
- A1 Hydrant Services for their technical expertise and tireless efforts in the remediation process.
- The dedicated local volunteers of the Municipality of Brockton, and in particular, the members of the Royal Canadian Legion Branch 102.
- The Municipalities of Brampton, Cambridge, Kitchener and London, and the Regional Municipalities of Peel and Waterloo, for their integral involvement in the remediation effort.
- A host of local plumbers from the Walkerton area, including Reed & Schaab, Sternall's Plumbing, South Bruce Plumbing, Richard Jaglewski Plumbing, Kinzie Plumbing, Rourke's Plumbing, J.D. Nichols Plumbing, Country Hearth Plumbing, B. Mitchell Plumbing and Howard's Plumbing and Electrical.
- Culligan Water Systems for their special efforts.
- J. MacArthur Siding for their efforts related to eavestrough replacement.
- Davidson Well Drilling for inspecting and disconnecting private wells from the potable water source.
- Motorola Canada for donating critical audio communications equipment that allowed the Walkerton Public Utilities Commission (PUC), A1 Hydrant Services, Culligan, the Brockton Fire Department, volunteer crews and OCWA staff to communicate with each other.
- The Canadian Tire Foundation for Families, for donating replacement showerheads and tap aerators for all the residents of Walkerton.
- Dahl Industries for providing fittings for draining water heaters.
- IPEX Inc. for providing watermain replacement pipe materials.
- Cambridge Brass for providing service mainstops and service valves.
- Clow Industries for providing fire hydrants.
- The Ontario Sewer and Watermain Contractors Association for providing main valves.
- Home Hardware in Walkerton for equipment donations.

1.0 Executive Summary

This report details the actions taken by the Ontario Clean Water Agency (OCWA) in order to remediate the Walkerton Water Supply and Distribution System after an outbreak *of Escherichia coli* O157:H7 in May 2000.

OCWA secured the services of GAP EnviroMicrobial Services (GAP) to help investigate the cause of the outbreak and to assess the effectiveness of OCWA's remediation work to support a recommendation to lift the boil water advisory for Walkerton.

The work plan focussed on two main areas: identification of the source(s) of contamination and evaluation of the security of the sources of water supply; and restoration of potable water supply, with the goal of restoring public confidence in the system.

Many agencies participated in the investigation of the cause of the outbreak, including: comprehensive hydrogeological testing of the three production wells by Golder Associates with assistance by Lotowater Ltd.; microbiological investigations by GAP EnviroMicrobial Services with assistance from OCWA; and investigations by the Bruce-Grey-Owen Sound Health Unit and Health Canada epidemiologists.

Findings reported by Golder Associates and GAP conclude that Well #5 was susceptible to bacterial contamination contained in surface runoff entering the well. Well #5 was immediately suspect due to its shallow construction and has not been operated since the outbreak.

GAP also reported a potential for surface water to influence Well #6 based on the observation of local surface water readings during pumping of the well; the presence of aerobic spore-forming bacteria, which are normally found in soil, in water samples from Well #6; and higher concentrations of chemicals such as nitrate and chloride at Well #6.

GAP also confirmed that capsulated coliform bacteria isolated from the distribution system were biochemically tested and found to be the same capsulated coliform bacteria isolated from Well #6, thus confirming the route of entry of these organisms into the distribution system through Well #6. As a precaution, Well #6 was removed from service by OCWA in late August. The Golder Associates report, dated mid-September 2000, also confirmed that Well #6 had a hydraulic connection to shallow water in the wetland and a nearby pond.

These findings have led to plans for installation of an interim treatment facility located in the area of Wells #6 and #7. This facility will consist of membrane filtration capable of removing bacteria-sized particles from the water, followed by chlorine disinfection. Once on-line, it will provide effective, multi-barrier treatment against bacterial contamination. Work will then potentially take place in the vicinity of Wells #6 and #7 to obtain a deeper, higher-volume and more-secure water supply at that location.

The remediation of the distribution system consisted of several components. These included watermain and standpipe flushing, dead-end elimination, distribution watermain swabbing, building plumbing disinfection, replacement of encrusted 100 mm diameter cast-iron watermains, and elimination of private well and cistern cross-connections. The work also included numerous valve and hydrant repairs and replacements.

OCWA retained the services of A1 Hydrant Services to perform the bulk of the distribution swabbing, building disinfection and repair work. Local plumbing companies and works crews from several other southwestern Ontario municipalities assisted with the work.

Several factors indicate that the measures taken have been effective in removing bacterial contamination associated with the outbreak from the distribution system. These factors include the following:

- Free chlorine residuals have increased throughout the distribution system with time, indicating a reduced chlorine demand due to the cleaning of the system.

- Since May 29, a total of approximately 2,500 distribution samples have been taken as part of OCWA's daily monitoring samples. As part of this program, there have been generally consistent sample results showing zero Total Coliforms in 21 distribution samples taken each day, with the exception of some incidents associated with rain and the operation of Well #6. Since Well #6 was removed from service, all samples showed zero Total Coliform, despite a major rainfall September 14-15 and extensive sampling at Well #7 during that period.

- The daily distribution samples have showed generally consistent low heterotrophic plate counts (HPCs) with exceptions as noted above. HPC values reported are usually <10.

- The audit sample results in the one-in-three household audit, conducted by the Ministry of the Environment (MOE) during the building-to-building disinfection program, showed similar results.

- The low incidence of aerobic spore counts, seen in samples taken during the MOE's audit of the building-to-building disinfection program, indicates that effective disinfection has occurred. Spore-forming bacteria are generally soil bacteria that are more commonly associated with surface water than groundwater. They are much more resistant to chlorine than coliforms and *E. coli*.

  The GAP report indicates that the presence of large numbers of spore formers throughout the distribution system would be expected even at normal disinfection levels, due to the demonstrated surface-water contamination and their presence in early samples of chlorinated water from Well #5. The absence of spore-forming bacteria confirms effective disinfection according to the GAP report.

- In addition to these sampling programs, another 2,399 samples were taken by the MOE following the building-to-building disinfection program. This sampling program, which was conducted on every house and building in the community, was conducted at least two weeks after the disinfection was completed. *E. coli* O157:H7 was not detected in any of these samples. There have been only four incidents of detection of non-pathogenic indicator *E. coli* in all of these samples.

- Preliminary results at the biofilm experiment site show that the disinfection and swabbing regimen carried out was successful in destroying an established population of *E. coli, E. coli* O157:H7, and Campylobacter jejuni inoculated into an established biofilm contained in sample 100 mm cast-iron pipes removed from the Walkerton distribution system.

These measures, along with the installation of OCWA's instrumentation and monitoring system, the installation of the filtration facility, and remediation work at Well #6, represent what OCWA believes to be the appropriate operational response to ensure a safe water system that supports the removal of the boil water advisory.

2.0 Introduction

In late May 2000, the Town of Walkerton, Ontario was affected by a serious outbreak of *Escherichia coli* O157:H7 (*E. coli*).

After the outbreak, a boil water advisory was issued, coupled with the remediation effort to restore the integrity of the community's water supply system.

This remediation effort was unprecedented in its scope and complexity. A number of organizations worked jointly on this initiative, including the Municipality of Brockton, the Ministry of the Environment, the Walkerton PUC, a number of specialized contractors and consultants, scores of volunteers, several other ministries of the Ontario Government, OCWA, and associated suppliers.

The purpose of this report is to document OCWA's efforts on behalf of the Walkerton Public Utilities Commission (PUC) to restore the integrity of Walkerton's water distribution system. This report will outline the remediation effort carried out by OCWA and its subcontractors.

The report outlines the various protocols that were developed, as well as the technical reasoning and rationale that contributed to the development of these protocols.

This report addresses the methodology of OCWA's involvement in this remediation effort, including the numerous operational components and the parallel communications efforts. To give the reader the best possible context, each technical section of the report is divided into the following headings:

Description
A definition of the technical and operational processes.

Objectives
The operational and procedural goals established for each initiative. These objectives range from general (e.g., prompt communication of an update) to extremely specific (e.g., minimum required levels of chlorine in the drinking water supply, measured in milligrams per litre (mg/L)).

Process
An outline of the approach adopted and the operational processes and techniques used.

Protocol
The operational procedures and protocols developed for each stage in the remediation process. Based on technical expertise, research and extensive consultation, these protocols comprise the blueprint for the operational activities undertaken.

Results/Conclusion
A description of the outcomes achieved.

2.1 Profile of the Ontario Clean Water Agency

The Ontario Clean Water Agency (OCWA) is a Crown corporation of the Ontario Government. The Agency operates, manages and maintains more than 400 water and wastewater facilities for more than 200 municipal clients across the province, making it the largest such operator in Canada.

The Agency was created on November 15, 1993 under the Capital Investment Plan Act with a mandate to provide reliable water and wastewater services to Ontario municipalities.

While the Agency is relatively new on the provincial landscape, its roots reach back more than 40 years to the Ontario Water Resources Commission.

In addition to its core services of water and wastewater operations and management, the Agency also provides a comprehensive set of specialized services to its clients, including OCWA's Environmental Management System, Project Management services and the latest in computerized water and wastewater treatment applications.

Additional information about OCWA and its range of services can be found at its web site, www.ocwa.com.

3.0 Background

Prior to the *E. coli* outbreak, which occurred in late May 2000, the Town of Walkerton's water supply and distribution system consisted of:

- three separate wells (Wells #5, #6 and #7);
- two water storage standpipes; and
- approximately 41 kilometres of water distribution piping, ranging from 12 mm to 400 mm in diameter.

The population serviced by this system is approximately 4,500 people. Approximately 2,300 properties are connected to the system, including commercial, residential, industrial and institutional users.

This water supply and distribution system is owned by the Municipality of Brockton and was operated by the Walkerton PUC since January 1953. The Walkerton PUC has complete responsibility for these facilities under the *Public Utilities Act*.

The Walkerton Water Supply and Distribution System is regulated by the Ministry of the Environment (MOE) under the *Environmental Protection Act* (EPA), *Ontario Water Resources Act* (OWRA) and Regulation 435-93. It operates under a Certificate of Approval (C of A).

On Sunday, May 21, 2000, the Bruce-Grey-Owen Sound Medical Officer of Health issued a Boil Water Advisory for the Town of Walkerton, Ontario. At that time, the system was being operated by the Walkerton PUC, which had also received operational input from Collingwood Utility Services.

On the morning of Thursday, May 25, 2000, the Walkerton Public Utilities Commission passed a resolution authorizing the retention of the Ontario Clean Water Agency to take over the operation and maintenance of the Walkerton Water Supply and Distribution System for a period of at least six months.

Representatives of the Ontario Clean Water Agency immediately met with Walkerton PUC staff, representatives from the Municipality of Brockton, the municipality's engineering consultants B.M. Ross, and the Ministry of the Environment to assess the needs of the system and to work on developing an action plan to address the situation.

By 12:00 noon on May 25, OCWA's operations personnel were actively involved on-site in Walkerton and had effectively taken over operations management of both the facility itself and the overall remediation effort.

At approximately 3:00 p.m. on May 25, the Ministry of the Environment issued a Field Order to the Municipality of Brockton, outlining specific requirements for a response to the Walkerton Water Supply and Distribution System contamination. OCWA worked with the Walkerton PUC, the Municipality of Brockton and the municipality's consultants to develop a response to the Field Order.

The requirements of the Field Order fell into two categories. The first dealt with the determination of the source of possible contamination. The second dealt with remediation of the system and protection of the municipal water supply.

Work to determine the source of possible contamination was generally carried out under the direction of the Municipality of Brockton, although on May 27, 2000, OCWA retained GAP EnviroMicrobial Services Inc. to provide advisory services including the conducting of an investigation to determine the source of the water contamination in Walkerton (see Appendix A). GAP EnviroMicrobial Services' mandate was to investigate and identify the potential source(s) of contamination and to assist OCWA staff with any issues relating to microbial contamination and disinfection procedures of the water distribution system as part of the remediation process.

Work falling under the second category (remediation and protection of the municipal water system) has been carried out primarily by OCWA on behalf of the Walkerton PUC. OCWA, along with the Walkerton PUC, developed its own Action Plan (Appendix B) to address the work for which the Agency would be responsible in the context of the remediation effort. As part of that overall remediation effort, OCWA established a program of flushing, swabbing and disinfecting the town's watermains. In addition, all service lines connecting the watermains to each building in the community were also flushed and disinfected.

As of this writing, OCWA is operating and maintaining the Walkerton Water Supply and Distribution System for the Walkerton Public Utilities Commission (PUC). The project is being operated as a Water Distribution Level 3 System.

4.0 Operational Approach and Timeline

The Municipality of Brockton prepared an Action Plan to respond to the contamination of the Walkerton Water Supply and Distribution System as required by the MOE field order #F0007721, dated May 25, 2000. The details of that Action Plan, which became the responsibility of OCWA after the PUC passed its resolution, are as follows:

- Ensure that the Well #7 overflow pipe cannot back flow from the surface into the well.
- Increase chlorine dosages to achieve a residual greater than, or equal to, 2.0 mg/L in the distribution system.
- Unless demand conditions do not permit (e.g., storage levels continue to decline), supply the system only from Wells #6 and #7. Only use Well #5 if necessary.
- Progressively flush the system moving away from the sources (wells).
- Monitor chlorine residuals to ensure fresh water is being supplied to each hydrant.
- Do not flush simultaneously at more than 2 locations.
- Sample for Total Coliforms and *E. coli* as follows:
  - daily until MOE declares results are satisfactory;
  - raw water and treated water at each operating well source; and
  - a minimum of 10 consumer locations throughout the distribution system.
- Take measures to ensure the fastest possible/practical turnaround time for lab results.
- Identify possible contamination sources:
  - raw water (aquifer);
  - pumphouses;
  - reservoirs (vents);
  - distribution system – breaks/repairs; new construction;
  - other connected sources – cisterns and wells; and
  - flooded basements on May 12 (following a torrential rainstorm).
- Subject to supply/demand considerations, isolate locations that may contribute contamination.
- Develop a plan to permanently secure locations that might contribute contamination.
- Document all events.
- Identify and begin to implement permanent solutions.

In response to these action items, OCWA prepared a supplementary action plan (Appendix B) that addressed these issues by:

- Assigning staff from OCWA's Operational Standards & Optimization unit to immediately assess the facilities, prepare OCWA's comprehensive Operations & Maintenance manuals and install OCWA's Outpost5™ remote monitoring system.

- Retaining GAP EnviroMicrobial Services to assist with the microbiological investigation of the cause and to provide expert advice regarding system remediation.

- Retaining A1 Hydrant Services to assist in planning and provide the expertise for the elimination of dead-ends, swabbing of watermains, disinfection of building plumbing systems and repairs to valves and hydrants.

- Immediately increasing chlorine dosages at the wells to provide for a free residual of 1.5 to 2.0 mg/L in the distribution system.

- Completing the flushing of the water system started by others.

- Taking immediate measures to secure the artesian drain line at Well #7 against contamination from backflow by installing a new drain line, a double-swing check-valve system, and instrumentation to monitor surface-water levels in the area of the drain outlet and shut down the well pump in the event of a flood condition.

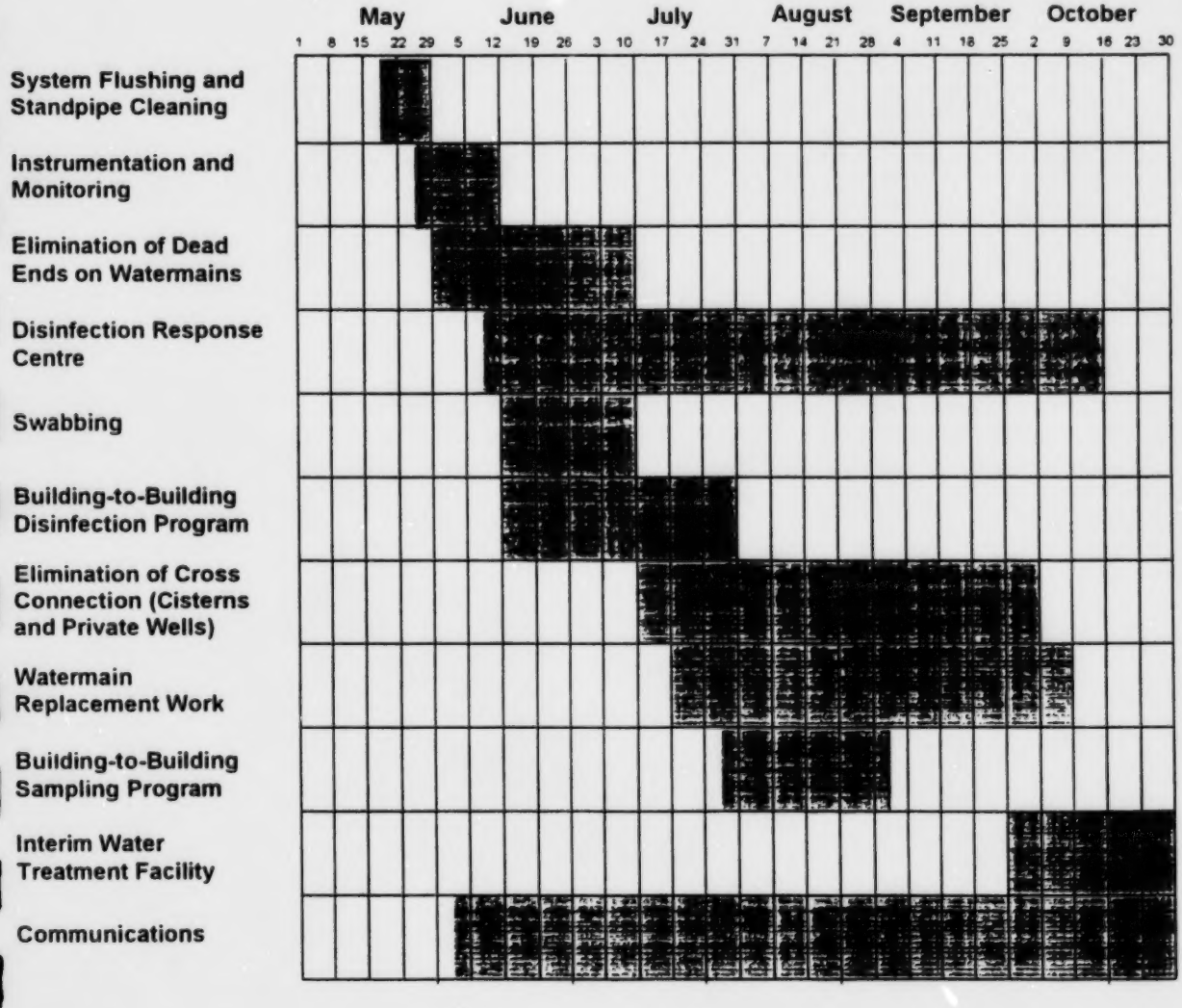
- Establishing a daily sampling program consisting of 21 locations in the distribution system, as well as raw and treated samples at each production well.

- Physically isolating Well #5 from the rest of the distribution system.

The sections that follow describe these actions in detail.

4.1 Timeline of Operational Activities

While the operational activities undertaken by OCWA as part of the overall remediation effort in Walkerton are outlined in detail in the following sections of the report, the following chart shows the timelines for each component. This chart illustrates the duration of the various operational components of the remediation, and can be used as a reference tool in the remainder of the report.


May
June
July
August
September
October
1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23 30
System Flushing and Standpipe Cleaning
Instrumentation and Monitoring
Elimination of Dead Ends on Watermains
Disinfection Response Centre
Swabbing
Building-to-Building Disinfection Program
Elimination of Cross Connection (Cisterns and Private Wells)
Watermain Replacement Work
Building-to-Building Sampling Program
Interim Water Treatment Facility
Communications

5.0 Operating Procedures and Monitoring Equipment

DESCRIPTION

In establishing a water supply and distribution system, two of the basic requirements are:

- development of standard operating and maintenance procedures; and
- development of contingency plans to prepare for non-standard occurrences within the system.

Operating and maintenance procedures include tasks to be carried out on a regular schedule to ensure that all necessary activities are being conducted in a timely and effective manner.

One of the basic operating requirements is the monitoring of water quality to ensure the adequacy of treatment methods. In order to achieve this, the Ontario Water Resources Act (OWRA) requires that certain minimum standards of daily and weekly monitoring be met. In order to enhance this basic level of vigilance, it is possible to upgrade monitoring to provide continuous assessment and delivery of information.

This type of automated instrumentation and monitoring, which provides continuous reporting to a central location, is state-of-the-art in the water and wastewater industry. This automated instrumentation can also be instructed to shut down pumps to prevent contamination of the distribution system, should preset parameters be exceeded.

Two key pieces of equipment that have been developed for this purpose are the turbidity monitor and the chlorine residual analyzer. A detailed description of all the equipment installed to date for the water system is provided in Appendix C.

Turbidity is a measure of the ability of light to pass through water and is an indicator of the presence of suspended material in the water. Monitoring of raw groundwater turbidity provides an immediate indication of water quality, its suitability for direct disinfection using chlorination, and an indication of its likelihood of being influenced by surface water. There is a maximum allowable level of turbidity in drinking water in Ontario, which was established for health and aesthetic reasons for the Ontario Drinking Water Objectives (ODWO) and was recently replaced by the Ontario Drinking Water Standards.

Chlorine residual is a measure of the amount of chlorine that has been added to the water supply and is available to disinfect bacterial contaminants. Monitoring of the treated water chlorine residual indicates whether there is sufficient chemical available to provide effective disinfection.

OBJECTIVES

- Establish standard procedures for the operation, maintenance and monitoring of the Walkerton Water Supply and Distribution System.

- Help ensure the prevention of any future water contamination by implementing monitoring and operations processes to prevent any water that does not meet provincial requirements for turbidity and/or chlorine residual from being delivered to the distribution system.

- Provide planning for contingency operation in the event of non-standard or emergency operating conditions.

PROCESS

One of the first activities OCWA initiated upon arriving in Walkerton was to assess and gauge the existing water monitoring capabilities of the community's water supply and distribution system. A key focal point within this assessment was determining the system's ability to measure factors such as flow, chlorination and turbidity.

As part of the overall remediation effort, OCWA brought in a technical services team to evaluate the existing monitoring and operations program and to propose any changes that appeared necessary to ensure the technical integrity of the system. This work included the installation of automated monitoring equipment to collect data and a Supervisory Control and Data Acquisition (SCADA) system to notify staff immediately should chlorine residual levels or turbidity move outside the acceptable range.

This phase of the project also entailed the development of operating manuals (available under separate cover) to establish clear procedures for the ongoing operation, maintenance and monitoring of the water supply and distribution system. Preparation of manuals included the development of contingency plans to establish procedures for immediate response should unplanned events occur. The development of this documentation was completed using previously established and proven programs used by OCWA at facilities throughout the province.

PROTOCOL

Chlorine Residual Analyzers

OCWA installed ProMinent D1C model chlorine residual analyzers throughout the Walkerton Water Supply and Distribution System. These units were installed at:

- Standpipe #1;
- Standpipe #2;
- Well #5;
- Well #6; and
- Well #7.

These units continuously monitor the chlorine residual by maintaining a flow of treated water past a CTE 1-mA-5mg/L probe. The discharge water from the unit is directed to a drain. If adjustments are made to the chlorination feed rate, the changes in the chlorine residual reading are reflected after approximately 45 seconds. The chlorine residual analyzer units are calibrated weekly.

Best Practices/Process Quality Control

The quality of the treatment process and distribution system is monitored regularly to meet both legislative and operational requirements. Sampling and testing (in plant and by an external laboratory) are necessary for a variety of parameters. The quality control parameters for the Walkerton facility include bacteriological analysis and physical-chemical analysis.

Process records are also kept in Walkerton at the #7 Well House. A daily log book is located at each well site along with any documentation that is determined to be required at each location. Treatment and distribution summaries are provided to the Ministry of the Environment and the Municipality of Brockton on a regular basis.

Standard Operating Procedures (SOPs), which are designed specifically for the treatment and distribution operation, are based on industry best practices which provide operations staff with a defined operational protocol. The following SOPs have been developed and are included for use at the Walkerton Water Supply and Distribution System:

- Outpost5™ Operation.
- Standpipe #1 Operation.
- Standpipe #2 Operation.
- Well Pump #5 Operation.
- Well Pump #6 Operation.
- Well Pump #7Operation.
- Sampling: Example Sample Submission Form.
- Sampling: Bacteriological Sampling Procedures.
- Sampling: Frequency and Location of Bacteriological Samples.
- Sampling: ODWO, which has been modified to reflect the Ontario Drinking Water Standards, and Quarterly Reporting.
- Sampling: Testing for Chlorine Residual, Hach DR 100 Chlorimeter.
- Sampling: Testing for Chlorine Residual, Hach Pocket Chlorimeter.
- Contingency: Chlorine Gas Cylinder Changing Procedure.
- Contingency: Well Pump Failure.
- Contingency: Standpipe Level/Pressure Failure.
- Contingency: Low Chlorine Residual Analyzer Reading.
- Contingency: Bacteriological Results Are Unacceptable.
- Contingency: Diesel Generator Fails to Start.
- Contingency: Low System Pressure.
- Contingency: Report of Contamination of Water.
- Contingency: Return to Outpost5™ Operation, Residual Failure.

All records of the process sampling and testing data are maintained at OCWA's Southampton Hub office.

RESULTS/CONCLUSIONS

- OCWA has prepared a comprehensive Operations and Maintenance manual for the Walkerton Water Supply and Distribution System, complete with Standard Operating Procedures.

- OCWA has increased the level of security for the water system by introducing continuous monitoring of chlorine residuals and turbidity.

6.0 Watermain Flushing and Standpipe Cleaning

DESCRIPTION

Watermain Flushing

Watermain flushing refers to the practice of opening fire hydrants to cause a large volume of water to pass through an isolated section of the watermain to remove settled and suspended material and contaminants. Watermain flushing is part of a recommended preventative maintenance program for any community's water distribution system. It is also a standard protocol used when distribution sampling indicates that contaminants are present within the system.

Standpipe Cleaning

A standpipe is a large, cylindrical water-storage structure, similar to a municipal water tower. Following the pumping and disinfection of well water, storage of the treated water is an essential component for the effective delivery of the water to the consumer. The main purposes for water-storage facilities include:

- reduction of the pump cycling on and off;
- provisions to store enough water to meet the peak daily demands of the service area;
- fire protection;
- reserve volume (alternative water supply in case of emergency); and
- provision of adequate and equalized pressure throughout the system.

A standpipe uses gravity to provide water pressure equalization for the water system. The Town of Walkerton's water distribution system has two separate standpipes. Standpipe #1 has a volume of 1,500 m^3 and Standpipe #2 has a volume of 3,383 m^3.

Standpipe cleaning was achieved by draining the standpipe completely, removing any sediment from the floor, and then refilling it with chlorinated water to the point of overflow. By achieving overflow, crews are assured that all of the interior surfaces of the standpipe have been in contact with the chlorinated water.

OBJECTIVES

- Clean the community's watermains and two standpipes.
- Purge bacteria, sediment and biofilm from the water distribution system.
- Eliminate cause(s) of positive test samples.

PROCESS

Following the issuing of the Boil Water Advisory on May 21, the Walkerton PUC initiated a program to flush various sections of the Town's watermain in an effort to purge bacteria from the water system.

When it became apparent that additional resources would be required to address the situation, the Walkerton PUC obtained the help of Collingwood Utility Services.

The Walkerton PUC, in cooperation with Collingwood Utility Services, continued to flush and examine the system. Much of the system was flushed over a period of approximately two days.

OCWA was retained as the new facility operator on May 25, 2000. At that time, the PUC's system flushing was nearing completion. OCWA immediately took part in completing the cleaning and flushing of the Walkerton Standpipe #1 by emptying and cleaning it prior to refilling it. The same process was used for Standpipe #2.

Following the completion of the watermain flushing and standpipe cleaning procedures, OCWA commenced an expanded distribution system sampling program at 21 separate locations throughout the distribution system in order to monitor water quality and assess the effectiveness of the flushing program.

PROTOCOL

- The section of the watermain to be flushed was isolated using distribution valves. Direction of flushing is controlled by opening an upstream valve in order to provide flushing water to the main and opening a hydrant on the downstream section to discharge the flushing water.

RESULTS/CONCLUSIONS

- Walkerton's water distribution system was flushed completely; some portions were flushed more than once. Bacteria and loose sediment was effectively removed from the distribution system.

- The Town's two standpipes were cleaned completely and disinfected. Water containing a minimum of 2 mg/L of chlorine was used to fill the standpipes, addressing any concerns of bacteria in the standpipes.

- There were no incidents of adverse samples reported from the distribution system for the period May 29 to June 12 immediately following the completion of the flushing program. This would indicate that the flushing operation was successful in removing suspended contaminants from the water distribution system. Adverse samples began to appear at the outset of the swabbing operations, as discussed in Section 8.0 of this report.

7.0 Elimination of Dead Ends on Watermains

DESCRIPTION

A dead end on a watermain is essentially a section of underground pipe that is capped and does not loop back to connect with any other section of the watermain, thereby not permitting continuous flow. These dead end sections may be the ends of pipes that are intended to facilitate future construction of undeveloped building lots on a street or may simply be at the dead end of a road due to a barrier to further construction such as a ravine or a stream.

Water does flow through a watermain with a dead end and is delivered to the houses and businesses along its route. However, since there is no free flow of water at the capped end of the pipe (and a limited demand), there is a lower-than-normal flow velocity. Over a period of time, a buildup of sediment, biofilm and minerals can develop in dead ends. This buildup of material could potentially harbour bacteria.

It is common practice to accommodate the flushing of dead ends by installing outlets, known as "blow-offs", which allow a high velocity of flow to be flushed out of the pipe. In some locations, fire hydrants are installed to achieve the same objective.

OBJECTIVES

- To locate and flush the dead end sections of Walkerton's water distribution system in order to support the effectiveness and integrity of the system-wide flushing initiative.

- To provide means for the future flushing of these dead ends as a normal operating maintenance procedure.

PROCESS

In Walkerton, many of the dead ends which existed did not include blow-offs or fire hydrants to facilitate adequate flushing.

In order to ensure the effective remediation of the distribution system, it was necessary to identify and eliminate dead end sections of the watermains within the system. In theory, these dead end sections in Walkerton could potentially harbour contamination from the original *E. coli* outbreak. For this reason, OCWA was intent on ensuring that each of these dead ends were addressed.

One of the first tasks undertaken was to identify the locations of the dead ends. During the assessment of the system-wide flushing program and during the planning stage of the swabbing program, OCWA conducted a review of the most recent mapping of the community's water distribution system. At the same time, OCWA consulted with the staff of Walkerton's PUC, since their knowledge of the system would be integral in helping to locate these dead end sections of watermain. This review resulted in the location of a significant number of dead end sections.

Based on this information, a plan was developed in conjunction with A1 Hydrant Services to locate and flush these dead end sections of watermain by installing blow-offs or hydrants where appropriate. (**NOTE**: In locations where future housing or business development was anticipated, fire hydrants were installed in order to accommodate the future development)

PROTOCOL

- OCWA staff reviewed available distribution system drawings and consulted with PUC staff and staff of A1 Hydrant Services to identify the locations of dead end watermains.
- Once a dead end location was identified (Appendix D), it was marked on a map and the necessary parts were obtained to install either a 2 inch (50 mm) blow-off line or a fire hydrant at the location.
- Installation work was commenced by PUC staff initially, but this project was turned over to the Repair Crew of A1 Hydrant Services once their services were retained.
- Once the blow-off line or fire hydrant was installed, the valve was opened in order to flush the water from that section of the watermain. The water was allowed to flow until the water became clear and indicated that a suitable chlorine residual was present.

RESULTS/CONCLUSION

- A total of 35 dead end locations were investigated between May 29 and July 31, 2000.
- A total of 11 of these dead ends were found to terminate within buildings and could therefore be effectively flushed through the building-to-building disinfection process.
- Fire hydrants were installed at 10 of the remaining locations and 2-inch blow-off lines were installed at the other 14 locations.
- Blow-offs were also installed at 28 service stub locations.
- This work effectively removed dead end locations that could not be previously flushed and which may have contained outbreak organisms if left unchecked.

8.0 Swabbing of the Water Distribution System

DESCRIPTION

Over time, most watermain piping develops a thin coating of organic material on its interior walls (Figure 1). This coating is known as biofilm and can consist of a variety of diverse bacteria populations. The thickness and composition of this biofilm material is dependent on a number of factors, including water chemistry, nutrients available in the water, pipe material and the velocity of the water flow within the pipe. Flow velocity may relate in significant part to the diameter of the pipe, as well as to its location in the distribution system. Unlined, cast-iron pipes are particularly susceptible to mineral encrustation, due to the rough surface of the interior pipe walls.

Other non-organic materials such as iron oxide (rust), magnesium and calcium may also build up and provide a base for the growth of biofilm. It is possible that bacteria in a water distribution system could become trapped in a developed biofilm material and be protected from the effects of chlorination. For this reason, swabbing and flushing are integral components of the overall system-remediation efforts.

Figure 1: A 50-year-old, 100 mm watermain shows extensive encrustation.

Swabbing is a mechanical method used to clean the interior surfaces of watermains by forcing a foam swab or plug through the pipes. This cleaning method effectively scours any material buildup and carbuncles that could potentially harbour and protect bacteria such as *E. coli* O157:H7 from disinfecting agents such as chlorine.

The swabbing process entails isolating a section of watermain and launching the swab into the watermain via a fire hydrant. Super-chlorinated water (300 mg/L was used in Walkerton) under pressure is used to force the swab through the watermain at a rate of approximately 2 m/s, scouring the material buildup from the interior surface of the pipe. Another fire hydrant at the receiving end is equipped with a special device to retrieve the swab, as well as a special hose, which is used to diffuse and redirect the flow of water preceding the swab.

The diameter of the swab is typically two inches larger than the diameter of the pipe into which it is inserted. This size differential, combined with the high water pressure used to propel the swab through the watermain, is the reason it is such an effective method of scouring the pipe's interior. The swab pushes along the inside walls of the pipe, cleaning and pushing out debris that is adhering to the pipe's interior. This process is repeated until the water discharged at the downstream end (ahead of the swab) shows no further sign of foreign material. This normally requires a minimum of four separate swabs being passed through a particular section of pipe.

Swabbing is usually done on pipes that have diameters of 100 mm (four inches) and greater. For smaller diameter pipes, there is a risk of the swabs becoming lodged in the pipe and causing a blockage. Since less water volume is required to fill these small diameter pipes, crews can usually create sufficient water pressure to duplicate this scouring or swabbing effect. On pipes larger than 100 mm in diameter, water pressure alone may not be sufficient to dislodge encrusted material from the interior walls of the pipe, hence the need for swabbing.

In Walkerton, pipe that was 100 mm or less in diameter was also found to contain a buildup of biofilm material. However, flow velocities could be achieved which were considered to be adequate to remove the majority of the biofilm inside these pipes. In order to confirm this belief, samples of this piping were taken after flushing and tested for the presence of biological material. Based on this research, it was determined that the swabbing of watermains in Walkerton could be limited to pipes of 150 mm (six inches) and greater in diameter.

OBJECTIVES

- Remove inorganic deposits, biofilm and any remaining sediment from the water distribution system.
- Eliminate any possible pathogens and protective materials that could harbour pathogenic growth in the future.
- Clear the distribution system of any possible contaminants prior to the beginning of the building-to-building disinfection program.

PROCESS

While system flushing is extremely effective in removing suspended bacteria from the distribution piping, it is not necessarily completely effective in dislodging all material buildup from within these pipes. The concern is that a buildup of biofilm material can actually harbour harmful bacteria and protect it from disinfecting agents such as chlorine. To address this issue, the Ministry of the Environment required the municipality to initiate a systematic program to swab the watermains of Walkerton's water distribution system.

The Town of Walkerton's water distribution system is comprised of 41 km of underground pipes, varying from 12.5 mm (1/2 inch) to 400 mm (16 inch) in diameter. Approximately 31 km of this underground system were found to be 150 mm in diameter or larger and were capable of being swabbed as part of this phase of the remediation program.

In order to allow the swabbing program and the subsequent building-to-building disinfection program to proceed, it was also necessary to carry out a program of locating, accessing and repairing, where necessary, the valves, fire hydrants and service connection valves within the distribution system. This work was carried out by a combination of A1 Hydrant Services staff and staff from a variety of southwestern Ontario municipalities who had volunteered their services.

Following the June 11 completion of the disinfection of the four main institutional buildings in Walkerton, the systematic swabbing program was started at Wells #6 and #7 and on the main supply watermain into the town on June 12. The watermain swabbing program was completed on July 10.

PROTOCOL

The swabbing was designed to follow a systematic pattern through the municipality, working away from the water sources (Wells #6 and #7 and the standpipes) and toward the unswabbed areas, with the intention of maintaining flow as much as possible from swabbed areas into unswabbed areas. The reason for this was to ensure that potential bacteria in an unswabbed area could not recontaminate an area that had already been swabbed.

As part of this systematic pattern, Walkerton was divided into 11 sections (Appendix E), based on two criteria:

1) the natural direction of water flow in the system; and
2) the locations of valves within the system, which could be closed in order to isolate unswabbed areas.

The following procedure was used to conduct the swabbing:

- A section of watermain was selected and isolated.
- A launcher was attached to a fire hydrant at the upstream end of the pipe section and a discharge (receiver) was placed at the hydrant at the downstream end of the pipe section.
- The foam swab (at least 50 mm larger in diameter than the watermain) was then inserted through the launcher and forced through the watermain by pumping highly chlorinated water (300 mg/L) behind it and opening the hydrant at the discharge end.
- Water exiting from the discharge end was dechlorinated using sodium thiosulfate.
- All residents were notified by the Disinfection Response Centre (Appendix F) at least one day before an area was scheduled to be swabbed and were instructed to shut off their internal plumbing valve to help ensure that they used no water during the swabbing procedure.
- The swab travelled between the launch location and the discharge location. Main valves on branch mains were shut off to direct the swab's course through the watermain system.
- Each section of pipe measuring 150 mm (six inches) in diameter or greater was swabbed a minimum of four times.
- Swabbing was repeated until the water exiting the pipe (ahead of the swab) was clear (i.e., contained no solids or colour).
- Appropriate water samples were taken after the first swab and forwarded for analysis.
- In cases where a swab became lodged in the watermain due to impediments in the pipe, excavation crews were called to excavate the watermain for a visual inspection.

- In some instances, it was possible to release swabs that were stuck at valves or fittings, or by built-up material within the pipes, by "surging" (i.e., reversing the direction of water flow one or more times and increasing the flow rate).

RESULTS/CONCLUSION

The following table lists the Town's watermains based on their diameters (ranging from 150 mm (6 inches) to 400 mm (16 inches)) and gives the lengths of each that were swabbed as part of this program.

Watermain Diameter	Length of Watermain Swabbed (km)
150 mm (6 inch)	15.952 km
200 mm (8 inch)	2.720 km
250 mm (10 inch)	7.220 km
300 mm (12 inch)	4.967 km
400 mm (16 inch)	0.100 km
Total	**30.959 km**

- Swabbing effectively removed and reduced the accumulated biofilm from within the large-diameter pipes. This is documented through the increase in the system chlorine residual and the low number of adverse samples reported immediately following the completion of the swabbing of all of the watermains.

- Preliminary results at the biofilm experiment site show that the disinfection and swabbing regimen carried out was successful in destroying an established population of *E. coli*, *E. coli* O157:H7, and *Campylobacter jejuni* inoculated into an established biofilm (refer to Section IIIF of the GAP report, Appendix A).

9.0 Watermain Replacement Work

DESCRIPTION

This refers to the systematic replacement of approximately 5 kilometres of 100 mm (four inch) diameter cast-iron watermain pipes within Walkerton's water distribution system. The material used to replace the watermain is polyvinyl chloride, which is a smooth-walled plastic which is not susceptible to the buildup of minerals to the same extent as metallic pipes (particularly iron). This material also does not support the growth of *Leptothrix* – an iron- and manganese-oxidizing bacteria, which was found to be a significant component of the biofilm in the existing cast-iron pipes.

OBJECTIVES

Minimize the opportunity for bacterial contamination to remain protected in biofilm growth within the Walkerton Water Supply and Distribution System. This objective is to be accomplished by replacing approximatey 5 km of 100 mm (four inch) cast-iron watermain, which contained such a buildup of material that they could not be cleaned by swabbing or flushing.

PROCESS

The pipes comprising Walkerton's distribution system range from 12.5 mm (1/2 inch) to 400 mm (16 inches) in diameter. During the swabbing program, operations crews discovered that the 100 mm diameter cast-iron watermain could not be effectively swabbed because of a buildup of calcium, magnesium and iron carbonate deposits. In some cases, the effective capacity of these pipes had actually been reduced by 50 per cent because of this accumulated buildup.

OCWA's microbiological consultant, Garry Palmateer (GAP), advised that he believed that the flushing of watermains less than 100 mm in diameter had effectively cleaned and disinfected those sections. Since the 100 mm cast-iron watermains could not be swabbed, the biofilm contained within those watermains could harbour contaminants. Garry Palmateer and OCWA recommended to the PUC that this pipe be scheduled for early replacement.

On Monday, July 24, 2000, the Ministry of the Environment issued a Field Order instructing the Municipality of Brockton and the PUC to replace the 100 mm (4 inch) sections of cast-iron watermain. Initially, approximately 3.5 km of this watermain were targeted for replacement. During the course of the work, the amount of 100 mm watermain identified within the system increased to 5 km. Following discussions with the Municipality and the PUC, OCWA was asked to arrange for and manage the pipe replacement process.

In order to complete this work as quickly as possible, OCWA immediately hired KMK Consultants Ltd. to work in conjunction with a survey crew provided by the Regional Municipality of Peel to make the necessary detailed survey of the streets where work was to be carried out.

Survey work began on July 27, 2000. KMK Consultants staff then proceeded to prepare the necessary drawings for construction. In parallel with this effort, OCWA Project Management staff worked with B.M. Ross & Associates (the engineering firm that historically provided services to Brockton) to prepare a Unit Price Tender Document. This document was effectively a schedule of unit prices covering various items of work.

At this stage, it was decided to divide the watermain replacement work into four separate sections in order to allow more than one contractor to be awarded work if this appeared to be the best way to complete the work on schedule. In order to avoid conflict in work areas, it was decided that a maximum of three contractors would be able to work concurrently.

Instead of undertaking a formal prequalification process to identify suitable contractors, tenders were invited from six specific contractors. These contractors were selected based on OCWA's past experience and recommendations from the two consultants and Municipality staff members. This approach was taken in order to save time and money and to avoid the need to qualify bidders for tendering.

Preliminary tender documents (without detailed drawings) were provided to the contractors on August 1, 2000 and a site meeting for prospective tenderers was held on August 3, 2000. After this, three test pits were excavated. Tenders were received from three firms on August 9, 2000. The remaining contractors indicated that they were too busy to properly respond to such a short schedule. KMK Consulting Engineers were retained to manage this process.

In order to expedite the work and in recognition of very similar pricing, each of the three tendering contractors was awarded a portion of the work on August 10, 2000.

The first three sections were awarded based on the anticipated production rate each contractor identified in the tender. The final section was retained, to be rewarded to the first contractor to complete their assigned section.

PROTOCOL

General

The original scope of work identified under this contract included the replacement of approximately 3.89 km of watermain on various streets in Walkerton. Tenders were invited from six (6) prospective tenderers. Three (3) tenders were submitted on August 9, 2000 for consideration by OCWA.

Based on the tenders submitted and the commitments made by the prospective Contractors, the Contract was broken into four (4) parts. Each of the interested Contractors was assigned one part, with the fourth part promised to the Contractor first able to complete the work.

Part 1, which consisted of watermain replacements on Colborne Street, Prince Street, Elgin Street, Napier Street from Yonge to Jackson, Alma Street from Princess to Elgin, and John Street, was awarded to Drexler Construction Limited of Rockwood.

Part 2, which consisted of Huron Street, Joseph Street, Alma Street from Huron to Campbell, Campbell Street, Mary Street, and Cayley Street was awarded to Omega Contractors of London.

Part 3, which included Napier Street from Gibson to Victoria, Scott Street, Peter Street, Victoria Street, Jackson Street and Queen Street was awarded to Arnott Construction Limited of Collingwood.

All three Contractors mobilized on site during the week of August 14, 2000.

Part 4, which included Orange Street and William Street, was ultimately awarded to Arnott Construction Limited.

Installation Procedure

All watermains were installed in accordance with the requirements of OPSS 701.

Generally, the Contractor commenced work near a planned connection point. The first length of pipe was installed with two (2) foam swabs to facilitate cleaning of the mains. A temporary connection to the surface was provided to permit the Contractor to charge the watermain and to facilitate the necessary hydrostatic pressure testing.

Watermain installation then proceeded with the Contractor installing prefabricated service tees, valves, and fittings as required. At logical points, the watermain installation was terminated to allow for testing and disinfection. Depending upon the system configuration and the Contractor's preference, the main would be tested at completion of a section or on a block-by-block basis.

A1 Hydrant Services was retained by all three of the Contractors to complete the swabbing and loading of the watermains, as well as the hydrostatic testing and disinfection of the new watermains. A1 Hydrants personnel first swabbed the watermain by forcing the previously inserted swabs out the exit locations and then prepared for a leakage test by pressurizing the mains to minimum 1035 kPa (150 psi).

After two hours the watermain was repressurized to the starting pressure and the amount of water used to obtain the required pressure was measured. Upon acceptance of the leakage test, A1 Hydrants inserted a chlorine slug (minimum 300 ppm) into the watermain and let it sit for minimum 3 hours. After flushing the main and letting it sit for 24 hrs, OCWA personnel obtained a minimum of two water samples per street and shipped them to the Central Ontario Analytical Laboratory for testing. It took approximately 48 hrs to obtain a faxed copy of the results. Once favourable results were received, the contractor was notified that servicing and connection could proceed.

Two methods were used by the Contractors to complete the water-service connections.

Method 1: The service connections were installed following the watermain installation but prior to testing and disinfection of the watermains. This installation procedure is typical for most Contractors and allows the entire system to be tested and disinfected simultaneously.

Method 2: The Contractor installed the main stop in the prefabricated service tee at the time of watermain installation. The new main was then be tested and disinfected prior to installation of the service connection laterals. The service connection tubing was then loaded with high-strength chlorine solution (i.e., a 100 ppm solution) for a minimum of three hours prior to installation. When the service tubing was installed, the contractor took the loaded tubing and installed the service from the new main directly to the existing service at property line. The high-strength chlorine solution then was flushed through the private service into the house and discharged at the first available tap. All service materials and fittings were chlorinated by A1 Hydrants personnel prior to connecting to service. This method

had the benefit of speeding up the installation and maintaining flow to the affected houses. All three Contractors ended up using this method.

After all service laterals were installed and services were transferred, the new watermains were connected to the existing municipal system.

Broken Watermain Protocol

If an existing watermain broke, a predetermined procedure was followed to repair the broken main and maintain integrity of the system. A1 Hydrants and PUC personnel were called to turn valves to shut off water to the affected area. The water was never completely shut off, requiring the contractor to make the repair with a small flow of water exiting at the break location. This was implemented to prevent debris from entering into the water system. All fittings, pipe etc. used for the repair were first thoroughly cleaned and chlorinated by A1 Hydrants personnel prior to placement over the break. Once the repair was complete, A1 Hydrants turned the valves back on and flushed water from closest hydrant.

Unusual Circumstances

Huron Street: existing watermain on opposite side of road than indicated on record drawings.

Encountered 100 mm (4") watermain on Catherine Street and Peter Street, required additional work.

Encountered 100 mm (4") watermain at Gibson Street, required additional work.

Encountered unmapped sanitary sewer lines along roads, requiring field adjustments of watermain installation to maintain appropriate separation.

In almost all of the contracts, encountered several existing water services using a push-on type of main connection with a large rock holding the main stop in place. If the service was slightly touched or the rock removed, the main stop would move and cause a leak.

Encountered water services that were abandoned by turning off the curb stop and not located. When installing the main, these were broken by the excavator.

Encountered 150 mm black-coated steel gasmain placed above and directly in the same trench as 150 mm watermain on Victoria at Napier St. E. and Prince St.

Encountered water flowing quickly into trench on Scott St. E., Peter St. and Catherine St. that required dewatering with several pumps.

Encountered several services that were constructed of lead pipe. Upon replacing these services with new Kitec tubing, all but two were found to have copper tubing on private property. Two services were completely replaced from the street into the existing houses. One lead service went between two houses on Colborne St. to South St. This house was given a new service from the stub on South St. to its backyard where copper pipe was found going into the basement.

The Elgin & Yonge connection location at the existing system was not as per the record drawings, requiring the contractor to carefully dig back to the 150 mm watermain within the centre of this street. The contractor was forced to reduce lane width to allow traffic to pass using signage personnel only.

Encountered 50 mm potable ABS piping at intersection of Yonge and Joseph. Fittings could not be sourced immediately for this connection. At this same location an additional unknown pipe was found to service three houses on Yonge St and the previously mentioned 50 mm pipe serviced the next three houses.

Encountered several existing watermains that did not have sufficient cover to prevent freezing due to frost penetration. Measured depths of cover were approximately 1.2 m - 1.5 m but was found to be only 0.75 m at the intersections of Huron & May and Huron & Maple.

Watermain Installed (in metres), categorized by contractor

Date (2000)	Omega	Arnott	Drexler	Daily Totals	Cumulative Total (metres)
August 17	75.2	41.0	0.0	116.2	116.20
August 18	102.8	58.5	0.0	161.3	277.50
August 21	142.4	144.0	22.1	308.5	586.00
August 22	108.7	93.0	212.3	414.0	1,000.00
August 23	139.9	39.3	193.2	372.4	1,372.40
August 24	129.4	103.0	56.1	288.5	1,660.90
August 25	78.9	25.2	25.0	129.2	1,790.05
August 28	128.0	104.0	241	473.0	2,263.05
August 29	96.6	39.5	150.5	286.6	2,549.65
August 30	75.0	69.0	122.8	266.8	2,816.45
August 31	125.1	114.4	75.4	314.9	3,131.35
September 1	62.0	58.2	87.0	207.2	3,338.55
September 5	88.3	62.0	81.7	232.0	3.670.55
September 6	103.5	78.0	140.2	321.7	3,992.25
September 7	149.0	17.1	12.2	178.3	4,170.55
September 8	20.9	12.8	0.0	33.7	4,204.25
September 11	0.0	0.0	0.0	0.0	4,204.25
September 12	13.6	0.0	0.0	13.6	4,217.85
September 13	132.8	19.2	0.0	152.0	4,369.85
September 14	124.2	0.0	4.2	128.4	4,498.25
September 15	30.5	0.0	0.0	30.5	4,528.75
September 18	22.3	0.0	30.3	52.6	4,581.35
September 19	17.7	7.1	26.6	51.4	4,632.75
September 20	22.4	0.0	19.1	41.5	4,674.25
September 21	33.9	0.0	2.1	36.0	4,710.25
September 22	1.0	0.0	17.9	18.9	4,729.15
September 25	0.3	16.6	16.3	33.2	4,762.35
September 26	0.0	0.0	22.6	22.6	4,784.95
September 27	12.7	13.5	24.5	50.7	4,835.65
September 28	0.0	29.0	0.0	29.0	4,864.65
October 2	0.0	0.0	144.6	144.6	5,009.25
October 3	0.0	0.0	2.3	2.3	5,011.55
October 4	0.0	0.0	26.0	26.0	5,037.55

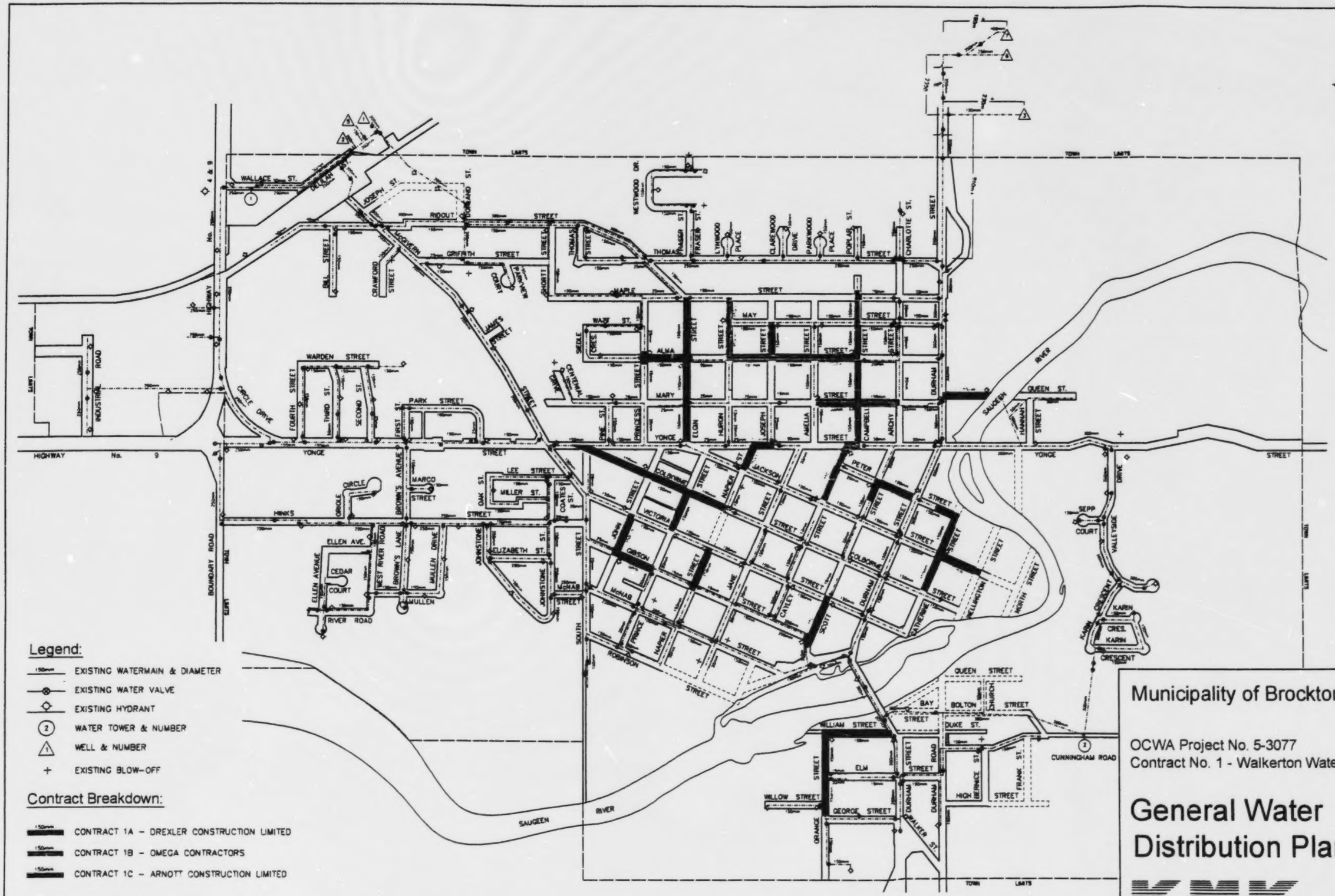
RESULTS/CONCLUSION

- The 100 mm cast-iron watermain, which had accumulated a significant amount of mineral encrustation and biofilm and was therefore not able to be cleaned by swabbing and flushing, was eliminated from the Walkerton Water Supply and Distribution System. This will minimize the growth of certain bacteria such as *Leptothrix*, which depends on specific metals and nutrients for their development. It will also significantly reduce the possibility that contaminants become sequestered and protected from the disinfection action of chlorine.

- The use of polyvinyl chloride as a replacement material will further minimize the future development of sediments, mineral encrustation and biofilm in this distribution system.

- The installation of approximately 5 km of 150 mm diameter polyvinyl chloride pipe will improve the capacity of the water system to carry flows for fire protection.

- This project included the replacement and/or extension of 215 residential water services with a plastic pipe material which is more resistant to biofilm growth than the original materials (primarily copper). Also included in the project was the replacement of some lead service connections. Some existing service connections were found to be connected by a plug fitting rather than by tapped and threaded connections. The replacement with a tapped fitting will improve the safety and security of the system.



Legend:

- EXISTING WATERMAIN & DIAMETER
- EXISTING WATER VALVE
- EXISTING HYDRANT
- (2) WATER TOWER & NUMBER
- (1) WELL & NUMBER
- \+ EXISTING BLOW-OFF

Contract Breakdown:

- CONTRACT 1A – DREXLER CONSTRUCTION LIMITED
- CONTRACT 1B – OMEGA CONTRACTORS
- CONTRACT 1C – ARNOTT CONSTRUCTION LIMITED

Note:

BASE INFORMATION FROM B.M. ROSS AND ASSOCIATES LIMITED CONSULTING ENGINEERS, DATED: 27 JULY 2000

Municipality of Brockton

OCWA Project No. 5-3077
Contract No. 1 - Walkerton Watermain Replacement

General Water Distribution Plan

KMK Consultants Limited
Consulting Engineers, Project Managers, Ecological Planners, Landscape Architects

SEPT 2000
N.T.S.
2211-D-44

10.0 Building-to-Building Disinfection Program

DESCRIPTION

This refers to the disinfection of the individual plumbing systems for each building connected to the Town of Walkerton's water distribution system (a total of 1,816 connections). For each building, the disinfection process required two days.

OBJECTIVES

- To ensure that every residential and commercial customer location in the Town of Walkerton was chlorinated and disinfected, thereby eliminating the possibility that any *E. coli* bacteria could survive.

- To gather and record information during the building visits on the existence of private wells, cisterns, boilers without backflow preventers, underground sprinkler systems, swimming pools, water-cooled air conditioners, water softeners and in-home water treatment systems for future follow-up.

PROCESS

At the outset of the remediation planning process, it was recognized that in addition to the overall disinfection of the water distribution system, there was also a need to thoroughly disinfect and clean the plumbing systems in every building in Walkerton.

Beginning on May 30, 2000, several strategic planning meetings were held between OCWA staff, OCWA's microbiological consultant (Garry Palmateer), the municipality's consultants, A1 Hydrant Services and a group of local plumbers who were familiar with the community's plumbing standards. The purpose of these meetings was to decide how to accomplish this building-to-building disinfection program.

Local plumbers raised the issue that as crews visited the various buildings in the community, they would likely discover a significant number of cisterns (tanks for storage of rainwater for reuse in the home), private wells and in-house water treatment appliances such as water softeners. Subsequently, measures were established to record and deal with issues arising from these types of equipment.

Once a preliminary program for the building-to-building disinfection was established, representatives of the Ministry of the Environment reviewed it and provided comments. The finalized procedure was also provided to the Medical Officer of Health for information and comment.

The basic procedure was provided by A1 Hydrant Services, which had previous experience with this type of work. The technical details of the procedure were developed specifically for Walkerton by representatives of the Municipality of Brockton, the Walkerton PUC, local plumbers and OCWA, with particular input by Garry Palmateer of GAP. Once developed, the procedure was submitted to the MOE for review and comment.

On the first day of the disinfection program, crews would visit a building and flush all taps, fixtures and water-using appliances with highly chlorinated water. Once this step was

completed, these fixtures would be shut and tagged. Crews would then move to the next building, leaving the highly chlorinated water in the building's plumbing system for a minimum of 12 hours (to ensure complete disinfection).

On day two, the crews would return and confirm that an adequate level of residual chlorine remained in the building's plumbing system. Once this was determined, they untagged the disinfected fixtures, flushed them with lower strength chlorinated water, and dechlorinated the wastewater using sodium thiosulfate.

Once these steps had been completed, the building was recorded as being officially disinfected.

The first buildings to be disinfected in this manner were the four main institutional buildings in Walkerton:

- Walkerton District Hospital;
- Brucelea Haven, Home for Seniors;
- Maple Court Villa, Seniors Residence; and
- Walkerton County Courthouse and Jail.

The disinfection of these buildings commenced at the hospital on June 6 and was completed at the Walkerton Jail on June 11.

The building-to-building disinfection program for all of Walkerton began on June 14 as the next phase of OCWA's Action Plan to restore clean and safe drinking water to the residents.

During the course of the building-to-building disinfection program, it became apparent that a significant number of cross connections existed between private water systems (cisterns and wells) and the municipal water supply (Section 11). In order to ensure that there would be no possibility of cross contamination from these sources, the Walkerton PUC passed a by-law on June 23 making such cross connections illegal. As of that date, the plan to document these cross connections for future remediation became one of the objectives of the building to building disinfection program.

PROTOCOL

The following section outlines the procedures established for the building-to-building disinfection program for the Walkerton Water Supply and Distribution System.

Note: Prior to carrying out the disinfection procedure outlined below, the watermain was cleaned by flushing or swabbing, depending on its size.

Disinfection Procedures

- Pre-determined sections of the distribution system were isolated systematically, proceeding from Wells #6 and #7 throughout the entire system.
- The section to be disinfected was isolated from the rest of the system using main shutoff valves. The remainder of the system was pressurized with the pumps and/or standpipes during the disinfection procedure.
- The section to be disinfected was charged with a minimum 350 mg/L chlorine solution for a minimum of 12 hours.
- Staff, under the direction of OCWA, entered all buildings fed by the watermain section being disinfected. All taps and plumbing fixtures were opened and flushed with the chlorinated water, and a chlorine residual of at least 200 mg/L was verified at each fixture using testing (litmus) paper.
- This disinfection work included exercising curb stop and inside shutoff valves, as well as flushing this chlorine solution through water heaters, water softeners, automatic dishwashers, washing machines and water connections to refrigerators.
- Once plumbing fixtures had been flushed, they were shut off, locked out of service and tagged (this process also included toilets).
- Following a minimum 12-hour contact time, staff returned to each building to confirm that a minimum chlorine residual of 200 mg/L was still present. They then untagged and flushed all disinfected fixtures. In the event a chlorine residual level of less than 50 mg/L was detected, the procedure was repeated.
- The charging of the buildings with the chlorine solution took place at approximately noon each day in order to allow for the minimum 12-hour contact period to elapse overnight. At approximately 8:00 a.m. the following day, flushing and dechlorination of that area would began.
- Chlorinated water was then dechlorinated using sodium thiosulfate.
- All operations were recorded by an independent inspector (Giffels Associates Limited). The inspector recorded the serial number of tags used, as well as the date, time, and address of the locations that had been disinfected.
- When entry to a building was not readily available, a locksmith, accompanied by a Police Officer and Provincial Officer, obtained entry to allow the disinfection to be carried out.
- Local plumbing firms assisted with the flushing and tagging of plumbing fixtures. These local plumbers also responded to any generic plumbing problems or issues that arose.
- Service connections to buildings were closed following the charging with the chlorine solution. This kept fire hydrants available for potential fire fighting situations.
- An audit sample for total coliform, *E. coli* and *Clostridium perfringens* analysis was conducted on the water supply in every third building at the time of the dechlorination of the households.
- At least two weeks following this initial testing, a second set of samples were taken at every single building for coliform and *E. coli*.
- Showerheads and tap aerators were disinfected and/or replaced as necessary.
- Representatives of Union Gas and Culligan Water Systems (Culligan) followed the disinfection crews to deal with any issues arising with respect to other equipment such as hot water heaters, water softeners and other point-of-use treatment systems.

Disinfection Sequence

- The Walkerton Water Supply and Distribution System was divided into 11 sections (Appendix E) or zones to facilitate the disinfection procedures.
- While the disinfection was in progress in the initial section, water pressure was generated via the town's two standpipes.
- The disinfection process moved from Wells #6 and #7 and progressed through the distribution system following the swabbing operations. It proceeded in a manner that allowed water to flow from completed areas into areas that had yet to be completed. This approach prevented the back-flow of water into areas that had already been disinfected, which could potentially contaminate that section.
- Building owners and occupants were notified by the Disinfection Response Centre (Appendix F) approximately 24 hours prior to the arrival of the swabbing and disinfection crews. The work performed by the Disinfection Response Centre and the volunteers maintained a high degree of goodwill during these challenging times.

RESULTS/CONCLUSION

- The building-to-building disinfection program began on June 14, 2000 and was completed on August 3, 2000. In that time, 1,816 separate buildings were disinfected.

- Each plumbing system of every building in the Town of Walkerton was disinfected as a direct result of the building-to-building disinfection program. This included traditional plumbing fixtures as well as appliances and other systems that made use of the municipal water supply.

- The MOE collected 664 samples to audit the effectiveness of the disinfection program. Fifteen of the 664 locations showed the presence of coliforms, but showed clear during re-sampling. *E. coli* was not detected during the audit sampling.

- The MOE sampled 2,299 locations at least two weeks following the completion of the building-to-building disinfection. Forty-one of these 2,299 locations showed the presence of coliforms during the initial sampling. All of the locations showed clear during two subsequent resamplings. There was one instance of the detection of *E. coli* which was confirmed to be a non-pathogenic, indicator type and was not detected in two subsequent resamples at that location.

- These results indicate that the disinfection process effectively eliminated any contamination from the plumbing systems in Walkerton.

The following table outlines the progress of the building-to-building disinfection crews.

BUILDING-TO-BUILDING DISINFECTION PROGRAM:
DAILY PROGRESS REPORT

Source: Giffels Reports

Date (2000)	Number of Houses Disinfected	Cumulative Total	
June 16/17	41	41	
June 18/19	44	85	
June 20/21	72	157	48 apartments completed (counted as 6 services)
June 22/23	64	221	
June 24/25	43	264	
June 26/27	50	314	
June 28/29	51	365	
July 4/5	86	451	
July 6/7	87	538	
July 8/9	33	571	100 apartments completed (counted as 1 service)
July 10/11	139	710	
July 12/13	115	825	
July 14/15	134	959	
July 17/18	134	1,093	
July 19/20	158	1,251	23 homes count for 68 units
July 21/22	193	1,444	
July 24/25	77	1,521	
July 26/27	93	1,614	Included 24-unit apartment & 24-unit motel.
July 27/28	5	1,619	
July 28/29	43	1,662	
July 29/30	7	1,669	
July 31/Aug. 1	76	1,745	Several apartments
Aug. 1/2	2	1,747	Tim Hortons & 1 Farm
Aug. 2/3	68	1,815	**Expected completion date.** Includes one 40-unit apartment building counted as 1
Aug. 8/9			Deficiency clean-up if required.
Aug. 10/11	1	1,816	A resident whose home was totally on cistern and originally refused to have home disinfected and subsequently changed his mind. Also disinfected Two-for-One Pizza after power to the location was turned on.
Aug. 23/24	3	Rechlorination	Morrison's Chip Wagon and Flavour, Flavour including apartment above Flavour, Flavour
Aug. 29/30	3	Rechlorination	308 Durham, Granny's Restaurant, and 121 William St.

11.0 Cisterns and Private Wells

DESCRIPTION

A cistern is a tank for storing water. In Walkerton, these water storage chambers are usually constructed of concrete blocks, which are then sealed to create a watertight holding area. Cisterns collect rainwater via a trough fixed under or along the eaves of the building. They are usually located in or near the building and are connected to the building's plumbing system through a pump. This configuration makes the rainwater in the cistern available for purposes such as washing clothes, washing dishes, bathing or as a source of drinking water. In some instances, a screen filters out debris.

In addition to these cisterns, 39 private wells were also found in Walkerton. Many of these were still in use as the sole source of water or in conjunction with the municipal water supply system. In the context of the objectives of the remediation program, these alternative water supply sources were treated in a similar fashion as cisterns.

OBJECTIVES

- Locate and record the existence of possible untreated water sources within the community.

- Ensure the integrity of the Walkerton Water Supply and Distribution System by eliminating any possible cross connections between an untreated water source and the Town's distribution system.

PROCESS

Due to the fact that the Walkerton municipal water system has historically provided hard water, the installation and use of cisterns as a source of soft water was widespread. In many cases, cistern water was the primary source of supply for water heaters, to provide soft water for washing and cleaning.

The practice of using cisterns was a concern in the Walkerton remediation effort because in most cases, these cisterns were cross-connected to the municipal water supply. This means that if the cistern ran dry, a valve would open which allowed water to flow from the municipal distribution system into the cistern or the building's plumbing system.

A primary concern was that in some cases, the pumps used on these systems were powerful enough that should the municipal water pressure drop below a certain threshold, the system could actually pump water from the cistern into the municipal water system. Since water in cisterns is not potable, this type of backflow posed a potential threat to the integrity of the water distribution system.

As a result of concerns raised by OCWA, on June 23, the Walkerton PUC passed a by-law making the cross connection of cisterns to the municipal water system illegal. This by-law led to an initiative to separate all such cross connections in the community following the disinfection program, but prior to final audit sampling if at all possible.

PROTOCOL

- As the disinfection crews visited each home, they assessed the possibility of cross connections between cisterns and/or private wells and the municipally-supplied plumbing system.
- During the building-to-building disinfection process, the disinfection team questioned residents/homeowners regarding the presence of special plumbing features, in particular cisterns, wells and boilers.
- The checklist was then used as a guide to the plumbers, who did a visual inspection for further cross connections or dead ends.
- A plumber's report was attached to the Disinfection Report and entered into the Disinfection Response Centre database for followup.
- Wherever possible, plumbers working along with the disinfection crews severed plumbed cross connections and capped them.
- As the work required to separate the system was often greater than the time available, arrangements were made to return at a later date. The work commonly included the separation of a common faucet where one side was municipally supplied (cold) and the other side came from a private system (hot) so that each had a separate faucet. In some houses, the plumbing had a number of connection points between the two systems, all of which had to be identified and severed.

RESULTS/CONCLUSION

- The process of separating the public water supply from the private systems was carried out over a period of approximately 12 weeks by local plumbers who were working on behalf of OCWA.

- In some cases, the private water supply system was abandoned entirely and replaced by water softening equipment. In most cases, the solution was to separate the two systems by severing the pipe connections or by installing taps with separate faucets.

- 151 water softeners were installed as part of the cistern decommissioning program due to the existing hard water sources in Walkerton.

- 471 cisterns were inspected and either disconnected or separated from the Municipality's potable water source.

- 39 wells were located, inspected and either disconnected or separated from the Municipality's potable water source.

- 135 boilers were equipped with backflow preventers as per the plumbing code.

- It is the opinion of OCWA that these measures have been successful in removing the risk of cross contamination of the public water supply from private sources.

12.0 Security of Water Supply

DESCRIPTION

In the development of any municipal water supply system, it is necessary to ensure that the supply is secure in terms of both quantity and quality. This process typically involves a review of all possible sources to determine the source that is most reliable in terms of these parameters and is then most economical in terms of capital and operating costs.

OBJECTIVES

- Ensure that safe and adequate water supplies were available to the Town of Walkerton to meet both the immediate short-term needs of removal of the Boil Water Advisory and the long-term needs of ongoing public health.

PROCESS

In view of the conclusion that the *E. coli* outbreak was due to the waterborne spread of the bacteria, it was necessary to determine and eliminate the source of contamination of the water supply. At an early stage of the investigation, it was determined that Well #5 was suspected as a source of contamination. This well was taken out of service at the time of the issuing of the Boil Water Advisory. Following this step, measures were taken to clean the system and assess all water sources for safety and security. As an additional security measure, a daily sampling program was established at the remaining wells and in the distribution system to identify any further contamination and provide evidence regarding the possible source.

As a contingency while this work was ongoing, it was decided to assess the possible long-term water-supply options meeting the need for safety and security.

As a preliminary step, a technology overview was carried out in mid-July and discussions were held between OCWA, the PUC, the Municipality, and the Ministry of the Environment and their respective consultants. Equipment manufacturers were contacted with a view to obtaining preliminary costs and delivery schedules as well as confirming the anticipated performance of various technologies.

As a result of this initiative, it was decided to retain a consultant to carry out a detailed study and develop a contingency plan to meet the need for both a short-term and long-term water supply should the remaining existing sources be identified as unsuitable.

On this basis, OCWA prepared "Terms of Reference" for a study and requested proposals from three engineering firms. On August 25 this work was awarded to R.V. Anderson Associates Ltd. Their schedule called for the study of all feasible alternatives and the development of a design for implementation, if necessary, of an immediate treatment capability for the remaining water supply from Wells #6 and #7.

Following heavy rains on the weekend of August 26 and 27, Well #6 had a Total Coliform result of 973 CFU/100 ml. Well #6 was taken out of service immediately. In view of this result and earlier evidence of aerobic spore-producing organisms at Well #6, it was decided to concentrate all efforts on the immediate provision of security of the water supply at Wells #6

and #7. The result of this was the preparation of the Walkerton Future Water Supply Study – Interim Report – Short Term Supply (Appendix G).

Following a meeting on September 14, the consultant was instructed to proceed with the preliminary design and pricing of an Interim Filtration System for Wells #6 and #7, and on September 21 the PUC authorized OCWA and the consultant to complete the design and carry out construction. On this basis, a new, interim filtration facility, capable of treating a minimum of 5,000 m^3/day to remove all pathogenic organisms, is being installed for a scheduled startup of October 31, 2000. The existing chlorine disinfection system will be incorporated into the design of the interim filtration facility to provide continued disinfection throughout the distribution system.

The Interim Report also includes recommendations regarding the remediation of the well field and the testing of Ultraviolet Disinfection Technology on the raw water from Wells #6 and #7, which may provide a short-term solution to the water supply needs of Walkerton. The proposed well-field improvements should rapidly provide a more secure supply, both from a quantity and a raw-water-quality point of view. These recommendations will be assessed and decided upon at a future time.

PROTOCOL

The Protocol followed in carrying out the work is based on the proposal dated August 21, 2000, by R.V. Anderson to the Walkerton PUC Titled Walkerton Public Utility Commission – Long-Term Water Supply Evaluation, Proposal for Services, it is attached as Appendix G. Due to the urgency raised by the results of the August 27 test result at Well #6, the proposed schedule has been compressed as much as possible.

RESULTS/CONCLUSION

- The result of this activity will be the immediate securing of a safe supply of water capable of meeting all short-term needs of the Town of Walkerton. The level of treatment will ensure that no contamination at the source can reach the distribution system because of a two-barrier treatment system: filtration followed by chlorine disinfection.

- A proposal has been made for the evaluation of a specific long-term solution for the Walkerton water supply. This would include redevelopment of the well field to provide secure groundwater sources from Wells #6 and #7, or a well to be developed in the future, combined with a two-barrier disinfection system which could include ultraviolet disinfection and chlorine disinfection along with further measures to protect the groundwater source if appropriate.

- Additional alternatives for the long-term water supply for the Town of Walkerton are also under evaluation.

13.0 Sampling Program

DESCRIPTION

The sampling program was established in order to test for total coliforms, heterotrophic plate counts (HPC) and *E. coli.*

OBJECTIVES

- To comply with the requirements of the Ontario Drinking Water Objectives (ODWO) and the Ontario Drinking Water Protection Regulation concerning distribution sampling.
- To monitor the bacteriological quality of the water in the distribution system.
- To comply with the requirements of the MOE field order.
- To determine the success of the remediation efforts.

PROCESS

On May 29, 2000, OCWA initiated a comprehensive daily sampling program of the distribution system consisting of 21 locations in the distribution system, plus raw and treated samples at each well in production. This sampling program has continued daily (including weekends) since that time. Approximately 630 samples are collected from the distribution system each month.

Although the sampling program was established when the ODWO required only 13 samples per month (collected weekly) from a distribution system the size of Walkerton's, this also exceeds the requirements of the Drinking Water Protection Regulation (Ontario Regulation 459/00) that came into force on August 26, 2000.

OCWA staff reviewed the distribution system drawings and established the sampling locations in key areas spread across the entire distribution grid. A sampling program with Central Ontario Laboratory had been established by Collingwood Utility Services staff the week prior to OCWA's involvement, and it was decided at that time to continue with this arrangement for continuity purposes.

PROTOCOL

The following procedures were used for the collection of bacteriological samples from the distribution system in Walkerton. The procedures are part of OCWA's Environmental Management System (EMS) procedures used at other facilities, including the facilities with ISO 14001 certification at South Peel.

Bacteriological Sampling Procedures

Sampling for bacteriological water-quality parameters requires a great deal of care since it is very easy to contaminate a sample. Of utmost importance is to recognize that bacteria are organisms which live everywhere including your hands and clothing. Therefore, good sampling protocol is necessary to ensure reliable results.

1. Use sterile bacteriological sample bottles only. Keep the bottles closed until immediately prior to collecting the sample. Never rinse the bottle.

2. Wash and dry your hands.

3. Do not collect a water sample from a hose or fire hydrant. Use a copper service. Use the specially designed blow-off when sampling a new water main.

4. Allow the sample line to flow at high rate for a minimum of five (5) minutes to flush the line thoroughly before collecting the sample.

5. Reduce the flow rate in the sample line, but maintain a water flow.

6. Carefully break the seal on the sample bottle cap and unscrew. Take great care not to contaminate the cap or the neck of the bottle with fingers. Do not put the cap down during sampling.

7. Avoiding splashes, fill the sample bottle up to the shoulder of the sample bottle. Replace the cap securely.

8. Shake the bottle five (5) times to help the dechlorinating agent (sodium thiosulfate) dissolve.

9. Label the bottle clearly with the time, date, location and type of water.

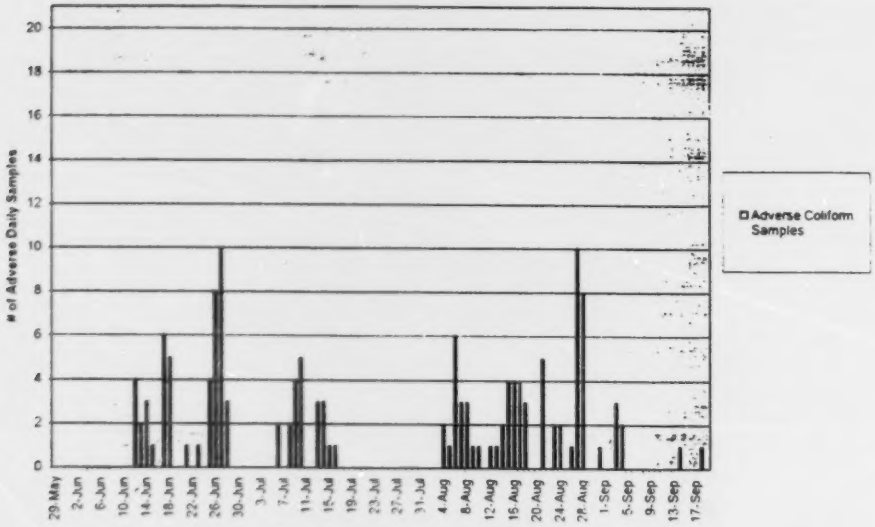
10. Bacteriological samples should preferrably be delivered to the laboratory within 24 hours. Never leave sample bottles in the sunshine or expose them to extreme temperatures.

11. The maximum time allowed for the samples to be delivered is 48 hours.

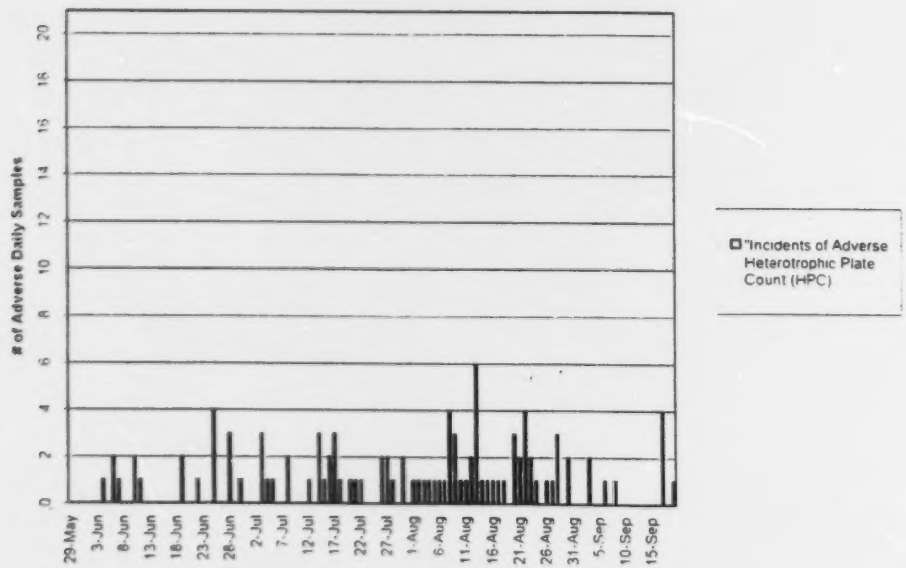
RESULTS/CONCLUSIONS

The following graphs show daily incidents of adverse sample results from within the distribution system for total coliforms, *E. coli* and Heterotrophic plate counts (HPC). As discussed above, these plots show how results were stabilized with the completion of the swabbing in mid-July, and then again later following the removal of Well #6 from operation at the end of August.

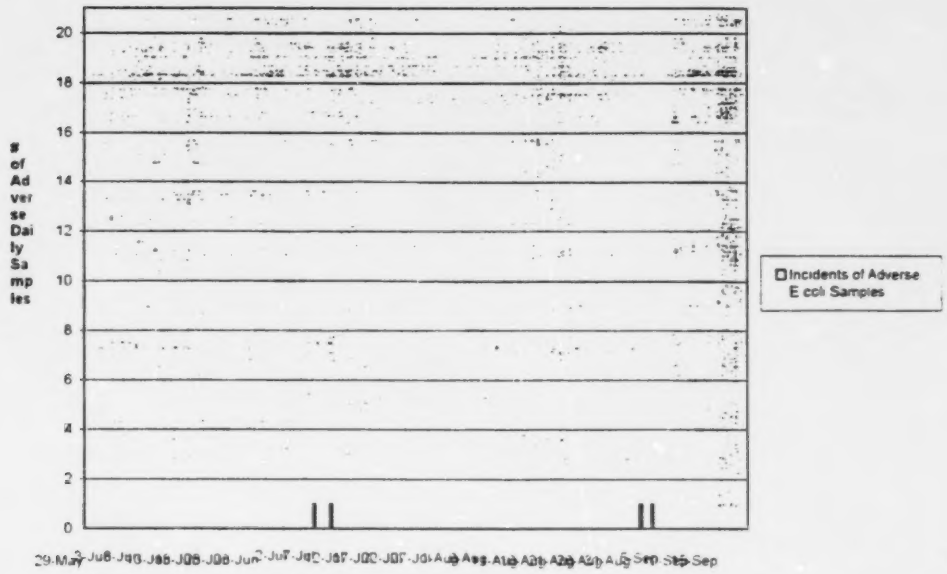
Incidents of Adverse Coliform Samples



Incidents of Adverse Heterotrophic Plate Count (HPC) Samples



Incidents of Adverse *E. coli* Samples



Following the completion of the initial distribution system flushing, no adverse bacteriological samples were detected in the distribution system for total coliforms from May 29 to June 11, 2000. A number of samples from the distribution system showed levels of total coliforms from June 12 to 14, with all distribution samples showing zero again for June 15 and 16. *E. coli* was not detected in any of these samples from the distribution system during this period.

Initially it was thought that these random occurrences of total coliforms within the distribution system were due to the ongoing swabbing operations in the distribution system which, by design, releases any attached bacterial growth from the side of the pipes into the water system. Similar incidents occurred throughout July, and incidents of adverse samples ceased completely between July 15 and August 4. The July 15 date was consistent with the completion of the swabbing on July 10, 2000.

Samples from Well #6 and Well #7 did not show any levels of total coliform or *E. coli* during this period until June 12, 14 and 15 when total coliforms were detected at both well locations.

Numerous incidents of total coliform detection, ranging from 1 to 4 locations each day, began to occur in early August throughout the distribution system, which cast some doubt on the theory that the earlier incidents were caused solely by swabbing. Considering the information now available through the hydrogeological work done at Wells #6 and #7, the adverse results may have also been associated with surface water contamination at Well #6. This hypothesis is further supported through the follow-up work done by GAP in early September.

Sample results reported for the period of September 1 to 4 showed positive levels of total coliforms present in three distribution samples for September 3, and two locations for September 4. In addition to this, a positive sample for *E. coli* (four colonies) was reported in

one location for September 1 (while all locations were zero for total coliforms) and another positive *E. coli* (two colonies) was reported for September 3 from a different location, with three locations showing total coliforms. All sample locations showed zero for total coliforms and *E. coli* for September 2.

GAP conducted some follow-up testing that showed the *E. coli* strains to be non-pathogenic indicator bacteria, and the coliform samples were identified as *Klebsiella pneumoniae*, a species of soil bacteria indicating surface water entry to the system. These bacteria are capable of producing a gelatinous capsule to protect themselves from chlorine. Total coliform counts were also present in the raw water samples from both Wells #6 and #7 from August 26 to September 3, with a count of >80 reported for Well #6 on August 28. GAP also showed that the coliform bacteria isolated from the distribution system were biochemically the same coliform bacteria isolated from Well #6, proving their entry to the system through Well #6.

It was at this time that Well #6 was taken out of service. There has not been another major incidence of adverse samples in the distribution system since that time.

A major rainfall occurred on September 14 and 15 in which approximately 48.5 mm of rain fell. OCWA staff carried out a sampling program approximately every two hours, beginning at 22:17 hrs on September 14 until 13:54 hours on September 15. A total of 10 large-volume samples were taken from Well #7 over that period, along with another three samples from points within the distribution system and a chlorinated control sample from Well #5. All samples were analyzed for total coliforms, *E. coli*, and aerobic spores. The results are detailed in the report prepared by Rick Turnbull of OCWA (Appendix H).

In summary, no incidents of total coliform detection were apparent in any of the samples collected; one sample from Well #7 showed a spore count of 1 colony; one sample from the distribution system showed a background count of 23 colonies. The control sample taken from Well #5 was chlorinated to a dosage of 2.5 mg/L. Despite the disinfection, the control sample from Well # 5 showed an aerobic spore count of 23 colonies with a background bacteria count of 32 colonies. The total coliforms and *E. coli* for the control sample was zero.

A review of the sample results for the 21 distribution samples and the raw and treated samples from Well #7 for the period of September 15 to 18 (a total of 90 samples) showed only one adverse sample with a total coliform count of 2 colonies.

This test has shown:

- Well #7 is more secure against surface contamination than Well #6, despite close to 50 mm of rainfall.
- Aerobic spore-forming bacteria are capable of surviving a chlorine dosage that effectively kills other coliforms and *E. coli*, as seen in the control sample from Well #5.
- The bacteriological quality of the distribution system is stabilized and large fluctuations in sample results has ceased since Well #6 was removed from service. These events were likely due to surface contamination at Well #6.

14.0 CONCLUSION

- Hydrogeological testing and bacteriological sampling have shown that local surface water can have an impact on the water quality at Well #5 and Well #6 and possibly to a lesser degree at Well #7. This is also supported by the historical incidents of adverse results seen at the three wells as presented in the GAP report, and the extensive growth of a filamentous soil bacteria *(Leptothrix)* in the distribution system also documented in the GAP report.

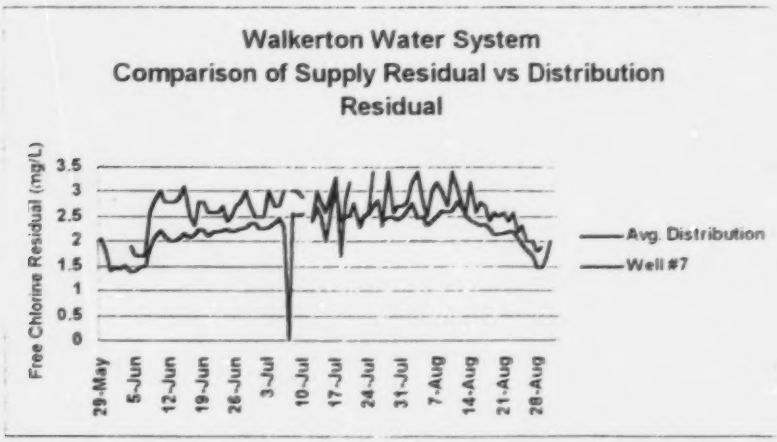
- In response to the security of the wells, Well #5 has remained out-of-service and will be ultimately decommissioned; Well #6 was removed from service by OCWA as a precaution at the end of August 2000; and a treatment facility is being constructed at the location of Wells #6 and #7. The treatment facility will include membrane filtration technology which will effectively remove bacteria-sized particles.

- OCWA has installed enhanced instrumentation at the well sites and in the distribution system that includes continuous chlorine residual and turbidity monitoring as an added measure of security for the water system. OCWA has also taken measures to protect the artesian drain line at Well #7 from flooding conditions by installing a mechanical backflow preventer and an electronic water level alarm for surface water in the area.

- Ongoing daily bacteriological testing demonstrates that the water distribution system has been effectively remediated by the effective removal of the outbreak organisms. This has been accomplished by a combination of flushing, elimination of dead ends, swabbing, replacement of encrusted cast-iron mains, and the disinfection of watermains and building plumbing systems.

- Audit sampling and follow-up sampling by the MOE also indicate that all outbreak organisms have been removed and the distribution remediation work has been effective.

- The convergence of the chlorine residual at Well #7 with the chlorine residual in the distribution system also supports the effective remediation of the water system, as shown in the graph below:



With the completion of the installation of the membrane filtration treatment plant, OCWA is confident that the remediation work completed and the safeguards put in place will provide a safe and secure water supply for the Town of Walkerton and facilitate the removal of the Boil Water Advisory.

APPENDIX A

GAP ENVIROMICROBIAL SERVICES INC REPORT

Investigations to trace the source of contamination and monitor disinfection of the drinking water system in Walkerton, Ontario

Prepared for the
Ontario Clean Water Agency (OCWA)

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Dan Van Bakel, Lily Gin, and Garry Palmateer,
GAP EnviroMicrobial Services Ltd.

and Rick Turnbull, OCWA

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EXECUTIVE SUMMARY

Contamination Sources of the Walkerton Drinking Water System

Results of the investigation to determine the origin of fecal contamination and *Escherichia coli* O157:H7, and how they entered the distribution system of Walkerton, have indicated that manure in the environment around Well 5 and Well 6 was the main contributing source. This is further corroborated by historical data from the past 3½ years which clearly shows both Well 5 and 6 having high incidences of coliform detection in both the raw and treated waters (Table 7), as well as laboratory investigations indicating the presence of the *Escherichia coli* O157:H7 outbreak strain in the environment around Well 6.

Soil samples from fields near wells 6 and 7 were negative for *E. coli* O157:H7, but it is possible that surface drainage following a major rain event could flow toward wells 6 and 7. During a rain event, runoff from the pasture adjacent to the wrecking yard would move towards Brighthope Kennels. It then runs through a culvert across Durham Road and into the marsh area surrounding wells 6 and 7. It is presently known that well 6 was impacted by surface water, as determined by hydrological measurements. Our observations show that there is significant potential for well 6 to be affected by surface runoff containing cow manure from the pasture adjacent to the wrecking yard.

Well 5 is shallow, and was impacted by surface water from near the pumphouse. This was determined by visual observations during test pumping. Manure contaminated surface water flowing around well 5 would be likely to be drawn into the well while pumping. Surface water flowing in a west to east direction from an area near Farm X was observed by PUC staff on the evening of May 12th. One possibility is that manure stored on a cement pad at Farm X contained the target bacteria (*E. coli* O157:H7 and *Campylobacter jejuni*), and was washed from the storage area to the zone adjacent to well 5. This surface water could then have been drawn into the well when the pump was in operation. It is also possible that the pump was not operating during the storm event of May 12th, but when it resumed operation the contaminated soil and surface water in proximity to well 5 was drawn into the well.

A second reason for contamination of well 5 by manure from Farm X is as follows. The rainfall event occurring from May 9th to 12th would have resulted in run-off from the manure storage area. This runoff then saturated the surrounding soil and allowed migration of bacteria through surface soils to the limestone bedrock. Here the bacteria could have entered the groundwater and flowed toward well 5. Hydrogeological studies carried out by Golder Associates have shown that when well 5 is pumping, the cone of influence is well beyond Farm X.

It is not known which of the above hypotheses concerning contamination of well 5 are correct, or if perhaps both circumstances had occurred.

In order to answer these questions, a microbiological tracer study was proposed. This would be accomplished by introducing a non-disease causing *E. coli* into the aquifer near the manure storage area on Farm X. Following introduction of the bacteria, well 5 would be pumped to waste. Samples would be taken over a period of 14 to 30 days to determine if the harmless tracer bacterium had reached the well. Details of this protocol are described in Appendix 1. If this particular scenario failed to demonstrate subsurface transport of an *E. coli* tracer from Farm X to well 5, the tracer might be also be introduced into surface water at the site of the "reversing spring". In either case, the rate of transport and survivability of a harmless *E. coli* surrogate representing *E. coli* O157:H7 could be established.

This experiment is necessary to provide crucial information on contamination of well 5. If the mechanism of contamination is not confirmed, it is unlikely that the public will be convinced that the remedial activities performed were adequate. Potential contamination of wells 6 and 7 should also be investigated using the microbiological tracer technique, to rule out potential impact sources surrounding these wells.

Rehabilitation of the Walkerton Distribution System.

The condition of water mains in the distribution system varied with their age and material type. Older 10 cm iron pipes, similar to those used for the biofilm study, were significantly encrusted by years of calcium, magnesium and iron carbonate accumulation. Encrustation of these pipes had reached a point where 50 percent of the pipe volume had been lost. Biofilm development in the 10 and 15 cm iron pipes was extensive, and may have developed from pumping surface water containing high concentrations of soil bacteria in the distribution system.

The filamentous, iron-oxidizing bacterium *Leptothrix* was shown to be the predominant organism in biofilm samples. Although most biofilm bacteria are non-disease causing, they can harbour pathogenic bacteria and protect them from chlorination. Removal of the biofilm by flushing, swabbing and super-chlorination was performed on the majority of the distribution system. GAP EnviroMicrobial Services recommended replacement of the 10 cm iron pipes with 15 cm polyvinyl chloride (PVC) pipes, which are less prone to biofilm formation. To further assess the effectiveness of the flushing, swabbing and super-chlorination, a biofilm study is being conducted. Results of this study are not available at this time, but will be published in a subsequent report.

In conclusion, well 5 was most likely the primary source of bacterial contamination in the distribution system. Wells 6 and 7 are less likely to have contributed to this contamination, but their impact is currently being assessed. Distribution system rehabilitation procedures appear to be effective based on bacterial testing procedures. However, final confirmation of their success in eliminating microbial pathogens has not been completed at this time.

SECTION I - INTRODUCTION

The ready availability of potable water is taken for granted by most of the western world. As contamination of the water supply in Walkerton has shown, this assumption can be a costly mistake.

Bacteria such as *Escherichia coli* (*E. coli*) are part of the normal gastrointestinal flora of all warm-blooded animals. Most strains of *E. coli* will not cause disease symptoms, and live with us as part of our normal microbial population. However, there are certain strains of *E. coli* that produce potent toxins, and these bacteria can cause disease and fatalities in animals and humans.

Konowalchuk *et al.* (1977) was the first to report that certain *E. coli* strains can produce potent toxins that can attack kidney cells. These toxins produced by *E. coli* are known as verotoxins, and they are closely related to the toxin produced by *Shigella dysenteriae.* Verotoxin producing *E. coli* strains (VTEC) have been shown to cause hemolytic uremic syndrome (HUS) and hemorrhagic colitis (HC) in humans. This has lead to their reclassification as enterohemorrhagic *E. coli* or EHEC.

There are many types of *E. coli* strains that can produce verotoxin, but in North America most outbreaks have been traced to one specific strain called *E. coli* O157:H7. The O157:H7 strain is particularly important because it is highly infectious in very small doses of only 10 to 100 cells (Tilden *et al.* 1996). Laboratories use specific tests that can identify and name *E. coli* strains, and these tests target two types of cell surface antigens, the "O" antigen and the "H" antigen.

Verotoxin producing *E. coli* strains have been found to be the causative agent in a number of outbreaks around the world. Most outbreaks associated with verotoxin producing *E. coli* have been from food sources or contact with infected animals or people, with only a small number resulting from potable water contamination. A large number of outbreaks have been listed occurring from 1989 to 1997 in the United Kingdom, Canada and the United States (Table 1).

One case of potable water contamination by verotoxin producing *E. coli* occurred in Cabool, Missouri, where four deaths were reported. Disturbances in the water distribution system were cited as the cause, including water meter replacements and line breaks (Geldreich *et al.* 1992). The field investigation that followed outlined the need for several changes in the operational maintenance of the distribution system.

A similar outbreak occurred in 1990 in Saitama, Japan, in which 42 confirmed cases of *E. coli* O157:H7 were identified in a nursery school. The school's drinking water was supplied from a contaminated well and *E. coli* O157:H7 was isolated directly in water from the taps in the school and the well (Akashi *et al.* 1994).

In 1992, an outbreak of *E. coli* O157:H7 occurred in South Africa which was shown to have originated from a contaminated river, after rains had washed both cattle feces and carcasses into the river. Almost 20% of water samples taken were positive for *E. coli* O157:H7, and in all instances the infected people had drunk from contaminated surface water (Isaacson *et al.* 1993).

Table 1. Waterborne outbreaks of *Escherichia coli* O157:H7 (Chapman, 2000)

Year	Location	Source	Cause	Reference
1989	Missouri	Unchlorinated drinking water	Collapsed water main	Swerdlow *et al.* 1990
1991	Oregon	Recreational water		Keene *et al.* 1994
1991	Scotland	Unchlorinated drinking water	Bovine feces	Dev *et al.* 1991
1993	South Africa	Unchlorinated drinking water		Isaacson *et al.* 1993
1994	Japan	Untreated well water		Akashi *et al.* 1994
1994	Scotland	Paddling pool		Brewster *et al.* 1994
1995	Illinois	Recreational water		CDCP 1996
1995	Scotland	Unchlorinated drinking water	Local stream	Jones *et al.* 1996
1997	Finland	Recreational water		Paunio *et al.* 1999

In 1995, an outbreak of *E. coli* O157:H7 and *Campylobacter jejuni* was reported in a small village in Fife, Scotland. Of the 765 residents, 711 came down with gastrointestinal illness and 633 were considered cases of *E. coli* O157:H7, although only 6 were confirmed and 8 confirmed for *C. jejuni*. Two of the *E. coli* O157 cases developed hemolytic uremic syndrome but made a full recovery. The outbreak was caused by contamination of the public water supply with treated sewage discharging into a local stream. At the time of the outbreak, watermain samples indicated high levels of total coliforms in the water (Jones and Roworth 1996).

In the case of Walkerton, if surface water contamination of groundwater wells is found to be the origin, questions arise as to the integrity of the wells, groundwater quality and the monitoring program in place to assure safety of the water supply. Parallels to the some of the above case studies can be made, and it is hoped that many lessons will be learned.

During the week of May 15, 2000, adverse drinking water results were received by the town of Walkerton, indicating drinking water supplies were contaminated. During that week a number of Walkerton residents reported gastrointestinal illnesses, and on May 21 a boil water order was placed on the town by the regional Medical Officer of Health. On May 25, the Ontario Clean Water Agency (OCWA) was asked to take over the water supply system in Walkerton, and became involved in work to rehabilitate the distribution system.

GAP EnviroMicrobial Services was retained by OCWA on May 27, 2000 to conduct an investigation to determine the source(s) of fecal waste that had contaminated water supplies in the town of Walkerton, Ontario, resulting in the *Escherichia coli* O157:H7 (*E. coli*) outbreak. The objectives of the contract included investigation and identification of the potential sources of contamination, and assistance to OCWA staff with any issues relating to microbial contamination and disinfection procedures of water distribution systems.

SECTION II. POLLUTION SOURCE INVESTIGATION

Introduction

The first phase of involvement of GAP EnviroMicrobial Services was to determine the source of the *E. coli* O157 outbreak. In order to perform this work, a number of field samples were taken and submitted to the laboratory for analysis. Environmental samples were taken to identify potential sources of contamination. Locations that could have impacted groundwater, wells or distribution system water were considered, and samples were taken from sources such as streams, ponds, marshes, ditch and surface water, reservoirs and soils. Laboratory analysis tested for the presence of total coliforms, *E. coli* and *E. coli* O157. The methods used for sample collection and analysis of these indicator organisms are located in Section IV - methods A, B, C and D. A brief summary of the importance of these bacteria will first be presented, followed by a summary of the investigative findings.

A. Introduction to Coliform and *E. coli* Bacteria

Coliforms and *E. coli* as water quality indicators.

The coliform bacteria are actually a group of bacteria that include many different genera, including *Escherichia* (*E. coli*), *Enterobacter*, *Shigella*, *Klebsiella* and *Citrobacter*. Coliform bacteria are common inhabitants of the intestines of warm-blooded animals, and for this reason can be used as indicators of fecal contamination. However some types of coliform bacteria, such as *Klebsiella* and *Citrobacter*, are also found naturally in soils and plant material. For this reason, the detection of total coliforms is not a highly specific indicator of fecal contamination, but it does provide information on contamination of potable waters by soils and surface waters. This in itself is a concern, and will indicate the potential for contamination of water supplies by pathogenic bacteria.

Within the coliform group, *E. coli* is a more specific indicator of fecal contamination. This bacterium does not survive well outside the gut, and are rarely found in environments not contaminated by fecal pollution. *E. coli* strains are normally present in the feces at high concentrations (10^7 to 10^8 cells per gram), therefore they are easier to detect in the environment than other coliform bacteria. For these reasons, the presence of *E. coli* will indicate recent contamination by fecal pollution.

It must be emphasized that testing for total coliforms and *E. coli* merely indicates that fecal contamination has occurred. Many of the strains detected, even *E. coli*, have very low virulence, and in themselves may not cause serious illness. However if an environment is found to be contaminated by fecal material, this indicates that more pathogenic strains may also be present, but in lower numbers. There is potential danger of other pathogenic microorganisms such as *Salmonella* (*Salmonella typhi*), *Campylobacter* (*Campylobacter jejuni*), *Shigella* (*Shigella dysenteriae*), *Vibrio* (*Vibrio cholerae*) *Cryptosporidium parvum*, *Giardia lamblia*, and even pathogenic *E. coli* strains (e.g. *E. coli* O157:H7) to be present in any water contaminated with fecal material. It

would be impossible to test for each type of pathogenic microorganism on a routine basis. Therefore we use indicators that are found in the feces in relatively high numbers to indicate their presence. *E. coli* are used as they have better detection levels in the environment, and therefore will provide more accurate estimations if fecal contamination has occurred.

Methods for detecting total coliforms and *E. coli* are described in Section IV. Basically, coliform detection is based on the ability of bacteria to produce acid and gas from lactose at 35°C. Bacteria in waters are filtered through a membrane that collects the bacteria on the surface, and the membrane is place on laboratory culture media. This media is specially designed to select and differentiate coliform bacteria (Figure 1). Each bacterial cell will grow to form a visible colony after 24 hours incubation, and the colonies can then be counted.

In order to differentiate *E. coli* strains from other coliforms, a unique characteristic of *E. coli* to produce an enzyme called β-glucuronidase is used. Other bacteria typically found in natural and fecal environments do not produce this enzyme. Special culture media will cause *E. coli* colonies to turn dark blue, whereas other colonies will remain colourless (Figure 1). Together with a high incubation temperature of 44.5 C, this allows the specific detection of *E. coli* strains.

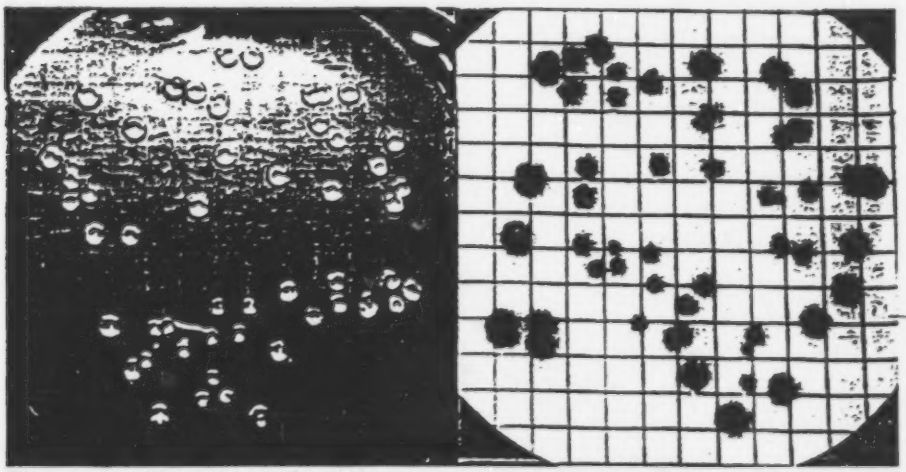

Figure 1. Detection of coliform bacteria (left) on mEndo LES agar and detection of *E. coli* bacteria (right) on mFC-BCIG agar.

E. coli O157:H7 detection and pathogenicity

There are a number of different pathogenic *E. coli* strains that can cause severe illness in animals and humans, including urinary tract infections, sepsis/meningitis, and enteric/ diarrheal diseases (Chart, 2000). One type of pathogenic *E. coli* is the verotoxin producing *E. coli* O157:H7, which was first recognized as a human pathogen by Riley *et al.* (1983) and Karmali *et al.* (1983). *E. coli* O157:H7 is highly infective and can cause disease symptoms in doses fewer than 50 viable cells (Tilden *et al.* 1996). Hemolytic uremic syndrome (HUS) and hemolytic colitis are caused by toxins that have entered the

blood stream through the gastrointestinal system. These disease symptoms occur because the toxins are particularly active in destroying cells lining the bowel, liver and kidneys. These toxins also recruit the immune system in order to increase the toxicity to these particular organs (Van der Kar *et al.* 1992, 1995).

The frequency of occurrence of *E. coli* O157:H7 in the environment is not known, however studies in the United States have shown that it is common in both dairy and beef cattle (Hancock *et al.* 1998). With a large number of dairy and beef cattle farms in Ontario, there is potential for *E. coli* O157:H7 to be present where farm runoff occurs.

Studies have indicated that once *E. coli* have entered the environment, they can survive for potentially long periods of time, for weeks (Lisle *et al.* 1998) or even months (Maule *et al.* 1999). Based on these studies, there is a high probability that *E. coli* O157:H7 could enter water sources through runoff from agricultural land. Once in drinking water, *E. coli* O157:H7 has also been shown to survive for periods of up to a month, with greater survivability occurring at 5°C as compared with 20°C (Rice *et al.* 1992).

Methods for the detection of *E. coli* O157:H7 are discussed in Section IV. *E. coli* O157:H7 is different from typical *E. coli* strains in that it does not produce the enzyme β-glucuronidase, and remains colourless and not blue on *E. coli* detection media. Other typical *E. coli* strains will always be found together with *E. coli* O157:H7, and they will serve as indicators of potential danger. However, different methods are required to specially detect *E. coli* O157:H7. These methods use a combination of techniques that detect specific antigens on the cell surface, and also certain biochemical tests. Methods to detect DNA from *E. coli* O157:H7 can also be used to identify their presence (Figure 2).

Figure 2. Gel electrophoresis image of *E. coli* O157:H7 as detected by BAX PCR. Lanes 8 and 10 show positive reactions identifying *E. coli* O157:H7 DNA present in the sample.

Once a strain of *E. coli* O157:H7 has been isolated from an environment, it must be tested for verotoxin production. Not all *E. coli* O157 strains are able to produce this toxin,

therefore this must be confirmed. Even within the *E. coli* O157:H7 group, there are different strains that have different characteristics. Further testing methods can determine the similarity between different O157 strains, and these are called DNA fingerprinting techniques (for example, pulsed-field gel electrophoresis or PFGE).

B. Pollution Source Identification – Chronology of Events

Initially Garry Palmateer, with the assistance of Rick Turnbull (OCWA), gathered information to determine the sequence of events leading up to the boil water order and subsequent outbreak. This involved several meetings with Steve Burns of B.M. Ross and Associates in which the operational practices and management of the entire distribution system of Walkerton by the PUC was described. In addition, data from routine well and distribution system sampling previously analysed by GAP EnviroMicrobial Services, from the period of October 1996 to April 2000, was summarized and reviewed (Table 7). This data showed significant incidence of coliform contamination at wells 5 and 6, indicating that these wells should be targeted for investigation.

Well 5 is located in the southwest corner of Walkerton, and feeds the distribution system with chlorinated water through hypochlorination. Wells 6 and 7, located to the northwest of Walkerton, were also described, and feed chlorinated water into the distribution system using chlorine gas treatment. It was suggested that chlorination was not occuring at Well 7 during the period of May 13th to May 17th.

During these meetings, information was obtained regarding time periods that each of the wells (5, 6 and 7) were in operation. This information clearly indicated that all three wells were in operation during the suspected contamination period of May 8 to May 24. All three wells were deemed suspect in contributing to contamination of the distribution system. Public health officials provided preliminary case maps showing the entire distribution system and the incidences of illness and death that occurred during the outbreak. It was obvious that the contamination had traveled throughout the distribution system, thereby implicating all three wells as potential sources. However, it was suggested that well 5 might be the main source as it was a shallow drilled well.

Initial investigations and general sampling

After initial fact gathering sessions, investigative sampling was conducted by Garry Palmateer and Rick Turnbull. Field samples were collected as described in Section IV (A). Samples were processed in the laboratory for total coliforms, *E. coli* and *E. coli* O157:H7 according to Sections IV (B, C and D). Bacterial enumerations from investigation samples are in Table 2 of the Appendix section (page 42).

During discussions with OCWA staff, it was indicated that a new water main had been installed on a dead-end main to supply the Saugeen Filter Supply on Highway 9. Concern was expressed that this section of new main may have been contaminated during

installation. It was observed at the same time that a nearby farm had a drainage pipe discharging into the ditch conveying this new water main. Since the area had heavy rainfall at approximately the same time the main was installed (May 9-13; Table 6), samples of drainage water and soil were taken near the drainage discharge and above the point of discharge. Samples were also taken from the new and old hydrants to obtain residual water from these old and new main sections. Results and sample descriptions are presented in Table 2. This initial set of soil samples, drainage water, and main water samples (samples 18734 – 18739) were taken on May 29th, while samples 18757 – 18761 were taken on the morning of May 30th.

Surface water was also observed in the ditch in front of the Energizer Co., and water flowing from the property was sampled (samples 18735 and 18734). Results indicated that only low levels of coliforms (400 cells per 100 mL) and no *E. coli* were isolated.

Sampling was continued on the south side of Highway 9, immediately west of the Energizer Co. property. A drainage pipe located on the side of the newly graded ditch appeared to carry drainage water from the adjacent farm property, and was located opposite the barn (Figure 3). Water flow was not observed from this drainage pipe at the time of sampling. A surface soil sample was obtained below the discharge area and a second subsurface sample was obtained 60 cm below grade. Both samples indicated typical soil coliform populations (100,000 and 200,000 cells per 100 g, respectively) and no *E. coli*. An upstream water sample from the area of the drainage pipe contained only coliform bacteria. These samples were taken due to concerns of possible contamination of a new water main extension that had been installed earlier in May. No evidence of residual fecal contamination was detected.

Figure 3. Farm discharge pipe on Hwy. 9, directly opposite the barn.

Water main samples were obtained from the new main extension, as well as from an old main, at hydrants in front of the Energizer Co. and the intersection of Highway 9 and Wallace Street. These samples showed no evidence of contamination.

On the evening of May 29th, sampling of well 5 raw water was conducted and analysis revealed 24 coliforms and 21 *E. coli* per 100 mL. These results suggest that contamination of the well water was recent, based on the ratio of coliforms to *E. coli*. Fecal waste entering groundwater usually contains 10 times more coliforms than *E. coli*. With time, the ratio will increase due to the faster die-off rate of *E. coli* than soil-borne coliforms. In this case, it appears that fecal waste entered directly into the aquifer of well 5 and did not carry any measurable soil or vegetation with it.

Subsequent investigations at well 5 indicated that the raw water contained 6 total coliforms and 7 *E. coli* per 100 mL (sample 18906). Spring water emerging from the ground approximately 15 m from well 5 contained 600 total coliforms and 80 *E. coli* per 100 mL, while an algal mat directly in the sample flow of groundwater contained 45,000 total coliforms and 900 *E. coli* per 100 mL (samples 18909 and 18905). Water emerging from a spring on the eastside of the road was found to contain 47 total coliforms and 14 *E. coli* per 100 mL (sample 18908).

The old town well #1 and a test well nearby are located close to well 5. A sample of discharge water from an overflow pipe at well 1 showed that both total coliforms *and E. coli* were absent (sample 18998). Water from well 1 was also tested and found to be free from contamination (sample 18999). Of interest was the algal and leaf material at the base of the test well because total coliforms were found at 310,000 per 100 mL and *E. coli* at 2,300 per 100 mL (sample 19003). Due to the ability of total coliforms and *E. coli* to survive longer in plant material containing a rich source of nutrients, sampling this material provides a history of the water discharging from the test well.

Further testing of the raw water from well 5 continued to detect coliforms and *E. coli*. Removal of the pump at well 5 on June 15th allowed swab and tubercule samples to be taken inside the pump casing (samples 19192, 19193, 19194). Analysis showed the presence of both total coliforms and *E. coli*. This indicates that contamination must have had occurred at this well over a considerable period of time, as these bacteria had become associated with the biofilm. *E. coli* O157:H7 was not recovered from these samples.

The overflow discharge from well 7 to the marsh area was sampled on the evening of May 29th (samples 18740, 18741), and found to be free of coliforms and *E. coli* . A soil sample (sample 18742), taken immediately below the overflow discharge was also negative for total coliforms and *E. coli* . A third sample (sample 18743) of an algal mat at this same location was found to be positive for both coliforms and *E. coli* (Figure 4). This indicates that fecal waste was present in the immediate vicinity of the overflow discharge from well 7, but did not definitively implicate this discharge as being contaminated. The sample was found to be negative for *E. coli* O157:H7.

A small artesian well discharge located about midway between wells 6 and 7 was found to be negative for both coliforms and *E. coli*. The investigation was continued in this location by taking samples of the surface water, approximately 30cm in depth, flowing around wells 6 and 7 (samples 18740 – 18750). Most of these samples were negative for coliforms and *E. coli* , with an exception in a surface soil (mud) sample taken at the culvert near well 6 (sample 18748). *E. coli* levels in this sample were similar to concentrations found in undiluted fecal waste. It was apparent from the grass lying in the direction of Well 6 that a large amount of surface water had recently flowed in this direction.

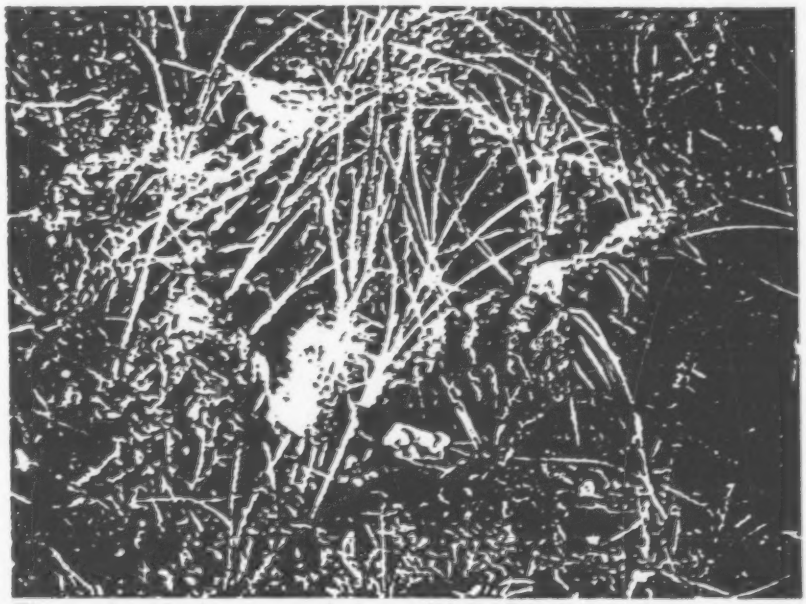

Figure 4. Algal mat sampled near Well #7.

On May 30th another part of the investigation commenced. Samples of water from the distribution system were obtained to establish if total coliforms, *E. coli* and specifically *E. coli* O157:H7 could still be recovered. This was done to provide a better understanding of how fecal waste containing *E. coli* O157:H7 had traveled throughout the distribution system, thereby causing the outbreak. Since the water mains contained high concentrations of free chlorine (2 to 5 mg/L), water samples remaining in lines to homes or businesses that had not been used during or after the outbreak were taken. Sampling sites were identified by PUC members, Jim Kieffer and Richard Field, and samples collected by G. Palmateer and R. Turnbull. The sample locations and rationale are shown in Table 2.

Results from distribution system samples showed an absence of total coliforms and *E. coli*. An exception was refrigerator water from 2 Third Street (sample 18767), with total coliforms and *E. coli* of 3 and 5 cells per 100 mL, respectively. *E. coli* O157:H7 was not detected using standard culturing methods or by DNA test methods.

OCWA staff, who were participating in flushing and swabbing of the water mains, also took samples whenever possible. Samples 19960 and 19961 (Table 2), containing rusty water, were negative for the presence of indicator bacteria.

A request was made for the public to report locations of water that had been stored from before the beginning of the outbreak. For example, a waterbed that had been filled prior to the outbreak was sampled, and no coliforms or *E. coli* were recovered (sample 19962). Another example is a stored water sample obtained on July 13th (sample 19093) that was also negative.

Investigation of producing zones in wells 5, 6 and 7.

Wells 5, 6, and 7 were investigated to determine zones that contributed to the contamination of each well. Results of water testing from producing zones of well 5 did not indicate with any degree of confidence where coliforms and *E. coli* were entering the well (samples 19401 to 19405). This was because very low coliform concentrations were recovered in only two of the samples taken: below 11.4 m and in the upper zone (5.5 m). Samples taken at producing zones of well 6 revealed no coliforms or *E. coli* in the 200 mL sample volumes analyzed (samples 19963 to 19966). Water samples were also taken from all zones of well 7, and were negative for coliforms and *E. coli* (samples 20977 to 20979; 20982 to 20984; 21292 to 21294; 21299).

An investigation of well 3 was conducted on July 6th, and all samples were negative for indicator bacteria. The investigation was then directed towards water producing zones of well 1, which had not been operating. Tests conducted on three samples of the different zones showed no evidence of contamination (samples 20982 to 20985).

Samples were also obtained from the undeveloped test well 8, which is located approximately 2.5km southwest of Walkerton, during a brief pre-examination of the well. The first flush was absent of coliforms and *E. coli*, but after allowing the well to flow for 5 minutes, coliforms were detected (sample 21870).

Aquifer and surface contamination investigations.

Investigation into the possible aquifer contamination around well 5 was conducted through a concerted regimen of soil sampling. A set of soil samples were taken at transects shown in Figure 5 (samples 19409 to 19423). Soil samples were obtained by scraping 2-3 cm of surface soil using a sterile scoop. The soil was transferred to sterile wide-mouth 500 mL plastic jars and sent for analysis to GAP EnviroMicrobial Services. Test results indicated that coliforms were present at various levels.

The first transect runs west from well 5 towards "Farm X" and includes sampling sites 1,2 and 3 (samples 19412 to 19414). The soil samples obtained from sites 4, 5, 6, 7 and 8, in a grid running through the woods north of well 5, showed high coliform and *E. coli* concentrations (samples 19415 to 19423). The moist soil at these sites were protected from sunlight by heavy tree cover, and provided an environment suitable for long term

survival of *E. coli* . The sites located in open field (sites 1, 2 and 3) were more exposed to environmental stresses such as sunlight, heat and drying. A second set of samples were obtained from sites 5a, 5a-7a and 7a, on a transect north of well 5 (samples 19967 to 19969). These soil samples also showed high levels of *E. coli*. *Escherichia coli* O157:H7 was not detected in these samples.

An investigation of the area around well 7 was conducted by sampling surface water that, in some cases, appeared to be spring water exiting from the ground. A culvert beside well 7, sampled on June 30th, showed 5 *E. coli* per 100 mL, while previous sampling of the spring between wells 6 and 7 contained 6 coliforms per 100 mL. *Escherichia coli* O157:H7 was not detected in these samples.

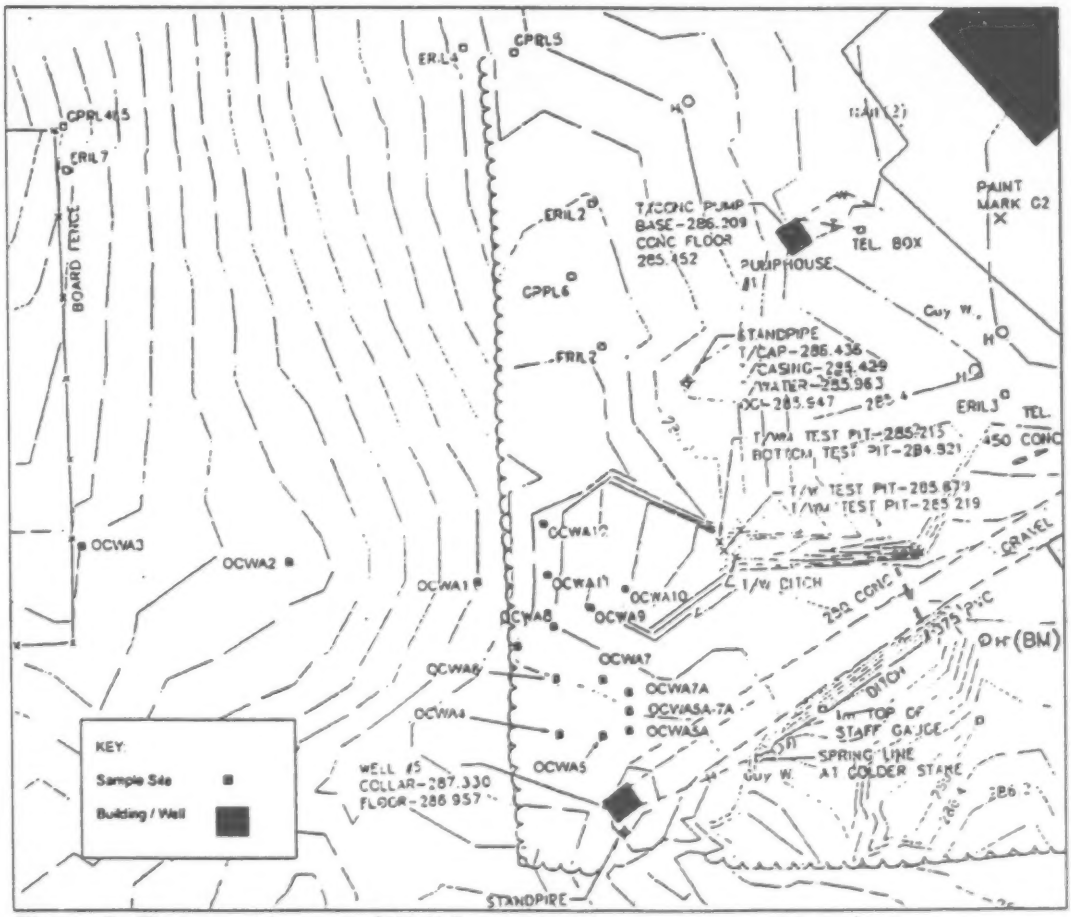

Figure 5. Topographic map of Well 5 area showing transect sample points.

The culvert closest to well 6, and the culvert at the roadside as it bends towards Durham Road, were also sampled. Low levels of coliforms and *E. coli* were detected (samples 20017, 20018).

On May 30th, the investigation continued in the area of wells 6 and 7. A significant reduction in the depth of surface water surrounding wells 6 and 7 occurred between

7:00 pm on May 29th and approximately 11:00 am on May 30th. The pumps of wells 6 and 7 were off on the evening of May 29th, and on during the morning of May 30th (Figure 6).

Surface water samples in the marsh and culverts under the road between wells 6 and 7 showed no fecal contamination, with the exception of a mud sample (sample 18748). The flow of water was significant enough to merit investigation of the drainage. The flow was followed upstream and away from wells 6 and 7, across the roadway, and through the marsh at the Brighthope Kennels, which was sampled (sample 18813) and found to contain 4,800 total coliforms and 100 *E. coli* per 100 mL.

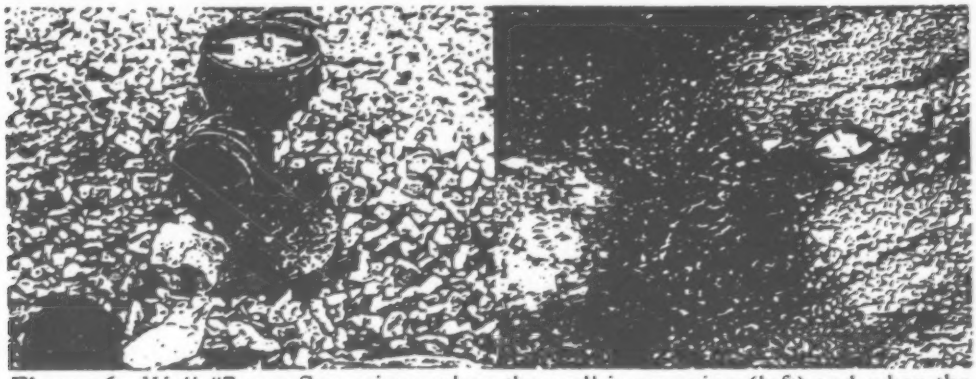

Figure 6. Well #7 overflow pipes when the well is pumping (left) and when the well is not pumping (right).

Tracking of the swamp drainage was continued upstream behind the auto wreckers to a pasture containing cattle on Farm Y (Figure 7). The small pond, on the east side of the abandoned rail line entering the wrecking yard, was also sampled (sample 18817). It was found to contain 2,500 total coliforms and 450 *E. coli* per 100 mL. It was thought that this pond may connect directly with the swamp water on the surface behind the auto wreckers.

Upon investigation of the Farm Y pasture, it was found that a small herd of beef cattle (25-30) routinely grazed in the field and were actually present at the time. Pond water used for cattle watering was tested at two sites (samples 18764, 18765), and contained 170 total coliforms and 260 *E. coli* at one site, and 1,100 total coliforms and 500 *E. coli* per 100 mL at the other. Analysis indicated that sample 18765 was negative for *E. coli* O157:H7.

Figure 7. Farm Y pasture showing the small pond that feeds the marsh area around Well 6.

Cattle feces located in the pasture near the swamp (sample 18763) contained total coliforms and *E. coli* at concentrations of 3.9×10^8 cells and 3.0×10^8 cells per 100 g, respectively. DNA analysis (PCR) indicated that this sample did not contain *E. coli* O157:H7. Cattle manure was encountered frequently, including examples of diarrhea, at the edge of the pasture and swamp as well as in the swamp.

The pasture slopes directly toward the marsh, such that a heavy rainfall in a short period of time could wash high concentrations of fecal waste into the swamp. This observation was confirmed on June 15th by a senior hydrogeologist with the MOE, Theo Beukeboom. He had examined the water flow from the pasture through the swamp towards wells 6 and 7, and confirmed that in a heavy rainfall event the field runoff to the marsh could impact surface waters surrounding wells 6 and 7. It has yet to be proven whether any infiltration to the groundwater had occurred, although daily water level records near wells 6 and 7 found that water levels fluctuated with pumping operations.

While investigating the flow of the swamp, cattle feces were observed in the flowing drainage. Samples were taken (samples 18810, 18811) upstream and downstream in an area that may have been impacted, and results showed the presence of coliforms only. This indicated that cattle feces were old and the *E. coli* had levels had decreased. Since these samples were collected approximately 4 m upstream and downstream, this appears the most likely reason.

Investigations were continued at the Farm Y pasture on June 2nd. Geese were also located near the pond water in the pasture and goose feces were found on the eastside of the pond. Goose fecal samples were tested and found to contain 2.5×10^5 *E. coli* per 100 g (sample 18820). In comparison, diffuse cattle feces contained from between $<10^8$ to 7.2×10^8 total coliforms per 100 g, and between 7×10^8 and 5.9×10^8 *E. coli* per 100 g (sample 18821, 18822). Analysis of cultures for *E. coli* O157:H7 using PCR were also negative for these samples.

An excavated pond approximately 3.2 metres below grade was observed approximately 100 metres from well 6, and was thought to be a potential source for contamination of this well site (Figure 8). Surface water tested at the east and west end of this pond on June 2nd contained 6 total coliforms and 7 *E. coli* per 100 mL and 110 total coliforms and 140 *E. coli* per 100 mL, respectively (samples 18992, 18993). It was considered a possibility that the pond water was a recharge source to the aquifer of wells 6 and 7, and therefore depth samples and more surface samples were taken. Sediment samples were also taken, as bacteria can survive longer in sediments than in the water column, and may provide a history of contamination. Results showed no coliforms or *E. coli* in sediments at the water interface, but coliforms and *E. coli* were present in 2 of 3 sediment samples. *Escherichia coli* O157:H7 was not detected.

Concerns about the possibility of the pond adjacent to well 6 being hydraulically connected to the well led to a more intensive study of this location. Water that fed the pond through a 7.5 cm black plastic pipe was connected to another pond on private property, which in turn was fed from an artesian spring. In previous sampling of the pond adjacent to well 6, coliforms and *E. coli* had been detected at the pond surface and in bottom sediments. A sample of drainage water taken from the pipe connected to the upper pond was found to contain coliforms and *E. coli* . The laboratory also recovered isolates of *E. coli* O157:H7 from this particular sample (sample 18997), which were confirmed in the lab by latex agglutination, PCR and biotyping.

Figure 8. Excavated pond near Well 6, thought to be contributing to well contamination.

The Ministry of Health laboratories tested the *E. coli* O157:H7 isolate using pulsed-field gel electrophoresis (PFGE) and verotoxin analysis. A strain isolated from sample 18997 was found to be positive for verotoxin production. It was also found that this isolate had

a DNA fingerprint identical to strains isolated from patients in Walkerton during the outbreak.

Concerns regarding the importance of detecting this isolate lead to further sampling of the upper pond, lower pond and connecting drainage. The source of the water contributing to the upper pond was not apparent at the time of sampling. The upper pond water contained 600 coliforms and 8 *E. coli* per 100 mL and the lower pond adjacent to well 6 contained 2 *E. coli* per 100 mL. The water draining from the black 7.5 cm pipe contained 6,000 coliforms and 28 *E. coli* per 100 ml. Large volume analyses (700 mL) of this water were found to be negative for the presence of *E. coli* O157:H7.

On September 1st, raw water from well 6 was sampled found to contain 2 coliforms and 0 *E. coli* per 500 mL.

GAP EnviroMicrobial Services Inc. has since completed testing of well 6 at the time of writing this report. It was indicated by OCWA that based on routine sample testing of wells 6 and 7, serious contamination of well 6 occurred around the time of August 28 and 29, 2000. Bacterial contamination of the distribution system was also detected. Tests have been conducted on coliforms recovered from selected sites in the distribution system and from well 6. Coliforms were identified using the BIOLOG detection system as *Klebsiella pneumoniae*, *Klebsiella mobilis* and *Klebsiella oxytoca*. These bacteria are primarily found in soil, and produce a large amount of capsular material on the cell surface. This capsule may have protected cells from the effects of chlorine in the distribution water, allowing their survival and detection.

C. Summary of Investigation Results

Well 5

Much attention has been focussed on well 5, and laboratory evidence verifies that well 5 was impacted by surface waters. Although *E. coli* O157:H7 was never recovered from raw, surface waters or soil samples taken at or around well 5, the presence of other *E. coli* strains shows evidence that this contamination may have been possible.

Total coliforms and *E. coli* were detected in well 5 raw water on a number of occasions during the investigation (May 29, June 5, 14, 19 and August 8; samples 18751, 18906, 19090, 19427 and 21786). Coliforms and *E. coli* were also detected on the well 5 casing, turbine and pump shaft (samples 19192, 19193 and 19194), presumably in biofilm associated with the well surfaces. The presence of fecal bacteria in these samples indicates that contamination had been occurring over an extended period of time, long enough to be associated with surface biofilms.

A number of surface water and soil samples taken in the area around well 5 were found to contain *E. coli* . Again, *E. coli* O157:H7 was not detected in any of these samples. These bacteria may not have been detected in the laboratory due to low detection levels in the

environment (below the sample volume analyzed), poor survival in the environment or sample timing.

The most significant surface sample found to contain *E. coli* was one of sediment and water taken from the "reversing spring". This spring normally flows away from well 5, however hydrogeologists with Golder Associates found that when they started the pump at well 5, the stream reversed direction, presumably due to water now being drawn into the well. Samples of the sediment in this stream contained 100,000 coliforms and 10,000 *E. coli* per 100 mL. If this stream contaminated well 5 raw water, it would likely have brought in significant amounts of fecal bacteria.

Other surface water samples around well 5 that contained *E coli* were discussed above in the investigation chronology. Soil and straw samples taken in close proximity to well 5 also contained *E. coli* (samples 18819, 18903, 19903, 19415-19419, 19423, 19967, 19969). Soil samples from control areas that should not be impacted by agricultural waste (samples 19409-19411) contained coliforms but no *E. coli* . This was expected since coliforms are found in all soils, but *E. coli* are only present in soil contaminated with fecal waste.

Well 6

E. coli were recovered from a number of surface water locations around well 6 (samples 18905, 18909, 19091, 19092). This indicates that surface water or runoff impacting groundwater around well 6 could be contaminated with bacteria associated with fecal contamination. During groundwater zone checks at well 6, coliforms were detected at very low levels (1 per 100 ml) in zone 4 (sample 19966), indicating that groundwater may be impacted by surface waters.

The most significant finding from the area around well 6 were the high *E. coli* counts in the pond by well 6. *E. coli* O157:H7 was isolated in pure culture from sample 18997, and found to be verotoxin positive. Sample 18997 was taken from water feeding into the excavated pond beside well 6. This sample was also found to contain high numbers of *E. coli*. A number of other samples taken from the pond water on the same day (samples 18992 to 18996) showed only low levels of coliforms and no *E. coli*, however only small volumes of water were obtained from these locations. It is probable that larger volumes would have made *E. coli* and possibly *E. coli* O157:H7 recovery possible.

Samples taken from pond water on the previous week showed 110 and 60 coliforms per 100 ml, and 140 and 70 *E. coli* per 100 ml. Water samples taken from the pond 12 days later recovered lower levels of *E. coli* (samples 19406, 19407 and 19408). Coliforms and *E. coli* were also recovered from pond sediment samples (samples 19424, 19425 and 19426). *E. coli* O157:H7 was not recovered from these pond water samples or sediments. It is possible that the detection level of *E. coli* O157:H7 was below the sample volume analyzed, or that the timing of the sampling events missed its occurrence.

E. coli O157:H7 was also detected in the area surrounding well 6 in samples taken at the Farm Z (samples 19528 and 19529) by using DNA test methods (polymerase chain reaction). Isolated colonies were not obtained from these samples and therefore could not be tested for verotoxin production. In environmental samples, older or damaged cells may not always recover and grow on laboratory culture media. This may have been the case with these samples, indicating that the contamination event was not recent. Most likely the water trough samples were contaminated by cattle.

Distribution system samples.

After issue of the boil water order in Walkerton, the distribution system was heavily chlorinated. This disinfection step destroyed almost all evidence of outbreak bacteria in the water system. In an attempt to isolate these bacteria from potable water, samples that had been stored by residents prior to chlorination were sought and tested.

Coliforms and *E. coli* were recovered at low levels from refrigerator water at 2 Third St., a private well at 104 Joseph, and a cistern from 6 Centennial (samples 18767, 20170, 21298). Both the well and cistern samples were of particular importance, as both sites were directly connected to the distribution system, and had the potential to contribute contamination into the system.

SECTION III. DISINFECTION OF THE WALKERTON WATER DISTRIBUTION SYSTEM

The second major function of GAP EnviroMicrobial Services was to consult on the rehabilitation of the water distribution system in Walkerton. This was accomplished by discussing concerns with the Bruce-Grey Health Unit, OCWA and the MOE. At times discussions also included the Town of Walkerton representative John Martin and the president of B.M. Ross, Steve Burns.

As part of the rehabilitation of the Walkerton distribution system, a program consisting of swabbing, flushing and super-chlorination of the watermains was established. All service lines connecting the mains to the homes and buildings were then flushed and chlorinated. As is further discussed below, many of the mains in Walkerton were found to contain significant amounts of biofilm. It is possible that bacteria introduced into a distribution system could become trapped in this biofilm material, and be protected from the effects of chlorination. For this reason, swabbing and flushing were important to remove as much of this material as possible. Chlorine is important in the treatment of potable water, and can be an effective disinfectant if the proper concentrations and contact times are maintained.

Chlorine as a disinfectant and biofilm formation in the watermains will be briefly reviewed to provide a context for the discussion of our results.

A. Review - Chlorine as a Disinfectant

Disinfection is the most important step in any water treatment process involving water usage for human consumption. In Ontario, as in most of North America, chlorine is the most commonly used disinfectant for this purpose. This chemical has a variety of utilities in the treatment process including taste and odour control, flocculation aid, and water quality maintenance throughout the distribution system, and as such is the reason for its commonplace existence in any water treatment system. However, chlorine is used primarily as a disinfectant. Chlorine disinfection is required when the drinking water supply originates from a surface source, when groundwater has the potential to be contaminated from surface sources (as in fractured limestone areas), or when the supply can be exposed to contamination during emergency events such as a flood or epidemic.

When chlorine gas is added to water it combines to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). HOCl can further react to form hypochlorite ion (ClO^-) and hydrogen (H^+). HOCl predominates when the water pH is below 7.5, and is the prime reactive agent involved in disinfection. It also makes up the majority of the free chlorine residual at and below this pH value. HOCl is very reactive and will quickly combine with several compounds in water (e.g. ammonia) to produce a combined chlorine residual (e.g. chloramine, dichloramine). When enough chlorine is added to the system to saturate the combined chlorine residual, then any additional chlorine will produce a free chlorine residual.

Of the chlorination techniques available, simple or marginal chlorination is the most common. However this method is the least effective if surface water is to be treated. This is primarily due to the initial free chlorine residual quickly reacting to form a combined residual, which diminishes inside the distribution system. A much more effective disinfection method is achieved through the use of free residual chlorination, whereby chlorine is added and maintained with a free residual 60% to 80% of the total residual. The amount of chlorine required to treat raw water depends on the concentration of organic compounds in the raw water, as these react with chlorine to form chlorinated organics. Chlorinated organics can be toxic, therefore to reduce their amount in treated water, chlorination often takes place after filtration.

Several factors determine the effectiveness of chlorination in controlling and preventing bacterial contamination in a distribution system, and include the following:

1. **Chlorine concentration and contact time.** Chlorine inactivation of bacteria, viruses and protozoan parasites is most easily understood using a relationship between chlorine concentration (in mg/L) and contact time (in minutes) known as the CT value. CT relationships are often developed under stringently controlled laboratory environments, and when applied to real world situations often require a great deal of judgement and past experience. White (1972), Jaroll *et al.* (1981) and Rice *et al.* (1982) have all developed CT value tables for a range of common pH values. The most critical factor in determining the correct CT is the contact time available in a system. For example, high flow systems tend to have short retention times, and would therefore require an increase in the free chlorine residual. The opposite would be true of slower flow systems.

   CT values become complicated when turbidity, organic load and biofilm accumulation are taken into account. Pathogen attachment to particles or biofilm can shield them from the effect of chlorine. In these cases higher chlorine concentrations and/or contact times would be required. Once a satisfactory CT value has been determined, chlorine concentrations must then be calculated mathematically. A common error is that short-circuiting, dead spaces and changes in flow rate due to peak demands are not accounted for.

2. **pH and temperature.** Chlorine efficacy is greatly influenced by water pH and temperature. Temperature will affect the dissociation rate of chlorine into HOCl and OCl^-, but the main factor affecting the relative concentrations of HOCl and OCl^- in the system is determined by pH. As described above, HOCl is the predominant species in solution below pH values of 7.5, while OCl^- becomes the predominant species in solution above pH 7.5. For example, at pH 7 and 0°C, chlorine dissociates into 87% HOCl and 13% OCl^-, while at pH 9 and 0°C, 6% HOCl and 94% OCl^- are formed.

   These relationships are important as HOCl acid will be the main biocidal agent in the system, and is 80 times more effective in killing *E. coli* than OCl^-. The reason for this is that HOCl can enter the microbial cell walls more easily than OCl^- (White 1972).

Inevitably, if the pH of the water is such that the OCl^- species predominates, it may be necessary to adjust the pH in order to shift the equilibrium back in favour of HOCl formation.

3. **Interfering substances and compounds.** Both chemical and physical interferences can affect chlorine. Chemical interference is often due to secondary chemical reactions occurring in solution with either the hypochlorous acid or the hypochlorite ion. Of particular importance is the reaction of chlorine with organic compounds, leading to the formation of organochlorines. These compounds have either little or no disinfection capability and can also be toxic or carcinogenic. Chlorine also reacts with certain types of inorganic compounds such as hydrogen sulfide, iron and manganese, and interferes with disinfection by creating sulphates, ferric hydroxides, and manganese dioxides. Biofilm bacteria such as iron and manganese-oxidizers can compound this problem in iron mains, as they release dissolved iron and manganese into the water.

   Physical interference occurs due to the attachment of microorganisms in particulate matter, where they are shielded from the effects of chlorine. Organic solids are the most effective at this, as they providing both protection and food for bacteria in the system. Biofilm formation is a very important factor contributing to reduced chlorine disinfection effectiveness.

B. Biofilm Formation in Pipes

Biofilm formation begins when microbial cells are removed from the aqueous phase and attach to solid surfaces. These immobilized cells can grow and produce extracellular polymers that help bind the cells to the surface (Characklis and Marshall 1990). As the biofilm increases in depth, it will stratify into different zones. A structure containing an anaerobic interior and aerobic exterior is often the result (Percival *et al.* 2000).

Common bacteria found in distribution system biofilms are the iron-oxidizing bacteria. These bacteria are normally found in soil and water, especially those containing dissolved iron and manganese. Typical iron-oxidizing bacteria include *Leptothrix*, *Gallionella*, and *Crenothrix*. These bacteria convert ferrous iron into insoluble ferric iron, and cells are often heavily encrusted with precipitated iron and manganese particles. Iron-oxidizing bacteria are long and thin in structure, and have gelantinous sheaths around the cells. Often very heavy iron precipitates will form on the sheaths, and the bacteria and iron will clump together to form large complexes. Many other types of bacterial cells can become trapped in this matrix and grow, and all of these cells attached and growing inside of pipes can form significant biofilm structures. These biofilms often contain very diverse bacterial populations (Figure 9).

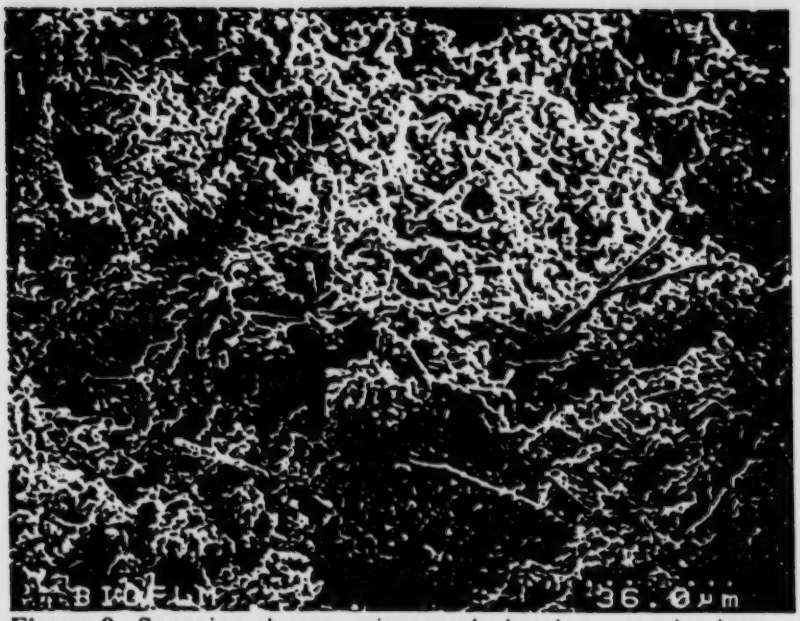

Figure 9. Scanning electron micrograph showing extensive iron-oxidizer colonization and biofilm formation in a 6 inch cast iron main taken from Walkerton.

The biofilm forming process is a very complex series of events involving water flow patterns and environmental parameters such as temperature and nutrient loading. The chain of events for biofilm formation is briefly outlined as follows:

1. Development of a surface conditioning film.
2. Events that bring the cells into close proximity with the surface.
3. Adhesion (reversible and irreversible) to the conditioned surface.
4. Colonization of the surface due to cell adsorption and growth.
5. Detachment of cells from the surface.

Scaling due to water hardness can provide a substrate for adherance of the biofilm. Biofilm will form in most metal pipes including cast iron, copper, lead and galvanized steel. Biofilms can actually lead to corrosion, due mostly to the growth of sulfate-reducing bacteria which thrive in the anaerobic cores of biofilm structures. Plastic pipes made of polyvinylchloride and polyethylene do not form biofilms to the same extent as metal pipes. As biofilms age, parts may detach and enter the distribution system. Detachment can occur for a number of reasons, including the sloughing of single cells or clusters of cells, or due to abrasion or swabbing of the pipes (Costerton *et al.* 1981).

Bacteria trapped in biofilm are can be protected from direct contact with the external environment. For this reason, disinfection systems useful for bacteria in the water phase may not be effective to kill bacteria in biofilm structures. Studies have shown that pathogenic microorganisms such as *E. coli*, *Salmonella*, *Yersinia*, *Campylobacter* and *Cryptosporidium* can all be harbored in the biofilm of water distribution systems (Percival *et al.*, 2000). Several reports have also shown that *E. coli* and *E. coli* O157:H7

can survive and grow in biofilms (Keevil *et al.* 1999; Le Chevallier *et al.* 1988). Many studies show that pathogenic bacteria introduced into a water distribution system can survive and grow in biofilms. Investigators have also shown that chlorine levels traditionally used in water treatment systems are inadequate to kill coliforms incorporated into biofilm. For example, *E. coli* was found to withstand 2400 times more chlorine when attached to a surface then when it was a free cell (Le Chevallier *et al.* 1988). Therefore the importance of biofilm formation in distribution pipes cannot be underestimated.

Control and disinfection of biofilm

Chlorine as a disinfectant is able to control biofilm formation, by eliminating cell loading and transport within the distribution system. Chlorine can also control biofilm, but only those that are thin and not well established. In older biofilms, chlorine is immediately reduced at the surface of the biofilm and cannot effectively penetrate the structure.

An alternative to the use of chlorine is chloramine. Chloramine is able to penetrate the biofilm structure, and can disrupt and loosen even older biofilms. Because chloramine is a less effective biocide on free-living microorganisms, it is important to maintain both chlorine and chloramine in the distribution system.

Various methods for controlling biofilm in a distribution system include maintaining chlorine and chloramines, and mechanical cleaning by methods such as swabbing. Another important factor is to make sure the degradable organic carbon in the system is low. Bacteria will only survive and grow if there are nutrients available, therefore reducing their food supply will control the sustainability of bacteria in water.

C. Consulting Services and Results Analysis

As has been discussed, disinfection of the Walkerton distribution system consisted of swabbing, flushing and super-chlorination of all watermains. Consulting provided by GAP EnviroMicrobial Services recommended an optimal disinfection protocol for disinfecting homes and buildings. It was recommended that 50 to 100 mg/L of free chlorine be maintained in the services, including all taps in the house, for a minimum of 12 hours, preferably 24 hours. It was also recommended to the MOE that the distribution system be allowed to stabilize after swabbing and flushing of mains and flushing and disinfection of the services.

As part of our consulting on the disinfection efficacy testing, GAP EnviroMicrobial Services recommended testing of every third home or building on each street for bacterial concentrations. Following disinfection, water was sampled for coliforms, *E. coli* and heterotrophic bacteria. In addition to this testing, GAP EnviroMicrobial Services recommended spore-forming bacteria also be enumerated. Spore-forming bacteria are more resistant to chorine than the coliform bacteria, and therefore are a useful indicator to

monitor of disinfection efficacy. More information on spore-forming bacteria, and the results of this survey, can be found below.

After swabbing, flushing and super-chlorination of the watermains commenced, a daily sampling program was instituted whereby bacterial levels at 30 sites in the distribution system and wells were monitored. Samples were analyzed for total coliforms, *E. coli* and heterotrophic bacteria. Initially results from the early stages of watermain disinfection showed increased coliform and heterotrophic bacterial populations. It was explained that this was due to biofilm material from the inner surface of the watermains was being pushed into the service lines. Results showed that following disinfection treatment of the services line to the homes, the coliform detection frequency decreased. Once entire areas of town had both the watermains and service line disinfected, this trend became more evident with only few exceptions.

Overall results show that the occurrence of adverse results in the distribution system, including coliform detection and heterotrophic bacterial counts above 500 cells per mL, were found to decrease over time. As well, the chlorine demand was found to decrease over time through the system, as shown by a steady rate of increase in the free chlorine residual with a constant chlorine dose. Both of these factors indicated that the effects of biofilm on the distribution system were slowly decreasing over time as the material was removed during the disinfection program. Following system stabilization, sporadic coliform detection was observed, indicating that biofilm remained in the system, either from swabbed biofilm that had not been completely flushed from the system or from pipes that had not been swabbed.

D. Total Aerobic Spore-former Results

Spore-forming bacteria are useful indicators of chlorine disinfection as they are more resistant to the effect of chlorine than may other types of bacteria. Bacterial spores are resting stages of the life cycle, are more resistant to factors such as chlorine and environmental stresses (e.g. dessication, heat) and survive much longer than vegetative cell forms. As they are more resistant to chlorination, they are useful to test the true efficacy of the chlorination treatment against a wide variety of bacterial species.

Initially we tested raw water and distribution water in Walkerton for the bacterium *Clostridium perfringens*. The methods used to detect *C. perfringens* are in Section IV (E). *C. perfringens* is an anaerobic, spore-forming rod commonly found in fecal material. However, the spores of *C. perfringens* were not detected in the raw water samples, and therefore were not a useful indicator bacterium. The detection of total aerobic spore-formers was substituted instead.

Total aerobic spore-formers consist of several genera of bacteria, with the majority of including the *Bacillus* group and to a lesser extent the *Actinomycetes*. *Bacillus* are common soil bacteria whose spores can survive for years. Most *Bacillus* species are harmless, and only a few are human pathogens (for example, *Bacillus anthracis* as the

causative agent of anthrax). It has been demonstrated that the spores of *Bacillus* species are considerably more resistant to free chlorine than coliform bacteria (Rice *et al.* 1996).

Spore-forming bacteria are often found in surface waters and less frequently in groundwater. Total aerobic spore-former concentrations in surface waters may be 10^2 to 10^4 CFU per 100 mL, whereas in groundwater the levels are usually < 10 CFU per 100 mL (Schubert 1975). A high concentration of spore-forming bacteria in groundwater is an indication of contamination by surface water. For example, aerobic spore concentrations in clear wells in four utilities in the United States ranged from 2 to 245 CFU per 100 mL (Rice *et al.* 1996).

Total aerobic spores were used in the disinfection efficacy assessment of the Walkerton distribution system for the following reasons. Spores were likely pumped throughout the entire distribution system on a regular basis following the rainfall events in mid-May 2000, due to surface water and soil contamination of the well 5 aquifer. Raw water from well 5 was tested, and found to contain total aerobic spore concentrations in the range of 30 to 1000 CFU per 500 mL. The presence of total aerobic spores in well 5 strongly suggests the impact of soil and/or surface water on the quality of groundwater supplies at this site.

Another reason for selecting aerobic spores is that the comparative chlorine resistance of the spores compared to coliform bacteria. This allows some estimation of the efficiency of the Walkerton swabbing and disinfection activities. Although only a few samples were tested, spore concentrations in the distribution system during water pumping from Well 5 (even when chlorinated) were estimated to exceed 100 CFU per 500 mL.

The comprehensive water sampling at every third home or building in the town and testing for coliform, *E. coli*, heterotrophic bacteria and total aerobic spore concentrations provides an informative data base concerning disinfection efficacy. The method used to enumerate total aerobic spore-formers is in the Section IV (F). A summary of the data (Table 3) shows that total aerobic spore concentrations were below the detection limit in the majority of distribution system samples. The most important finding is that these extremely chlorine-resistant spores have been reduced to low levels with only a few exceptions. Aerobic spore concentrations ranged from 0 to greater than 2400 CFU/500 mL, while most results were less than 10 CFU/500 mL.

When comparing chlorine resistance of the spores to that of *E. coli*, it is safe to assume that the survival of *E. coli* in the distribution system or on biofilm surfaces is highly unlikely. In particular, it is unlikely that *E. coli* 0157:H7 or *Campylobacter jejuni* have survived the swabbing and chlorination regime.

E. Biofilm Analysis in Walkerton Distribution Pipes

Samples of Pipe Flushings

During the swabbing and flushing procedures of the town watermains, OCWA submitted samples of flushed materials to be tested for coliforms and *E. coli*. Results of this survey are in Table 4. Coliforms were detected in pipe biofilm samples 20002 and 20990, and in material flushed from pipes (samples 19531, 19532 at hydrants #44 and #58, respectively). Both coliforms and *E. coli* were detected in wood chips that had been flushed from distribution pipes (sample 20714).

Escherichia coli O157:H7 was detected by DNA detection methods in material flushed from hydrant #44 (sample 19531). Pure cultures could not be isolated from this sample, and it could therefore not be tested for verotoxin production. Since coliforms but not *E. coli* were recovered from this sample on laboratory culture media, the *E. coli* cells present may have been damaged and non-recoverable on laboratory media.

Additional samples of water were taken from a number of sites during flushing and swabbing of a section of water main to determine if coliforms and *E. coli* were removed from the pipe surface (Figure 11). Water samples were obtained from the reddish discharge to the streets. Samples were also taken of the post swab water that contained 200 to 300 mg/L of free chlorine, and analyzed for coliforms and *E. coli*. All of the samples taken were negative for the presence of either coliforms or *E. coli* (samples 20165 – 20168, 20179, 20180, 20294 – 20296).

To further investigate the presence of biofilm on the mains, a 50 year old, 10 cm diameter pipe was found that contained 2 to 4 mm of biofilm (Figure 12). To better understand the significance of the biofilm, samples were aseptically removed, and found to contain coliform bacteria. A scanning electron micrograph of the biofilm revealed a high concentration of the filamentous bacterium *Leptothrix*. *Leptothrix* are iron and manganese-oxidizing bacteria that are naturally found in soil, but are also found in wells containing water with elevated iron and manganese. Other pipe samples were obtained that were made of copper, iron, galvanized steel, and polyvinyl chloride and polyethylene plastics. Pictures of the pipes are shown in figures 13 and 14.

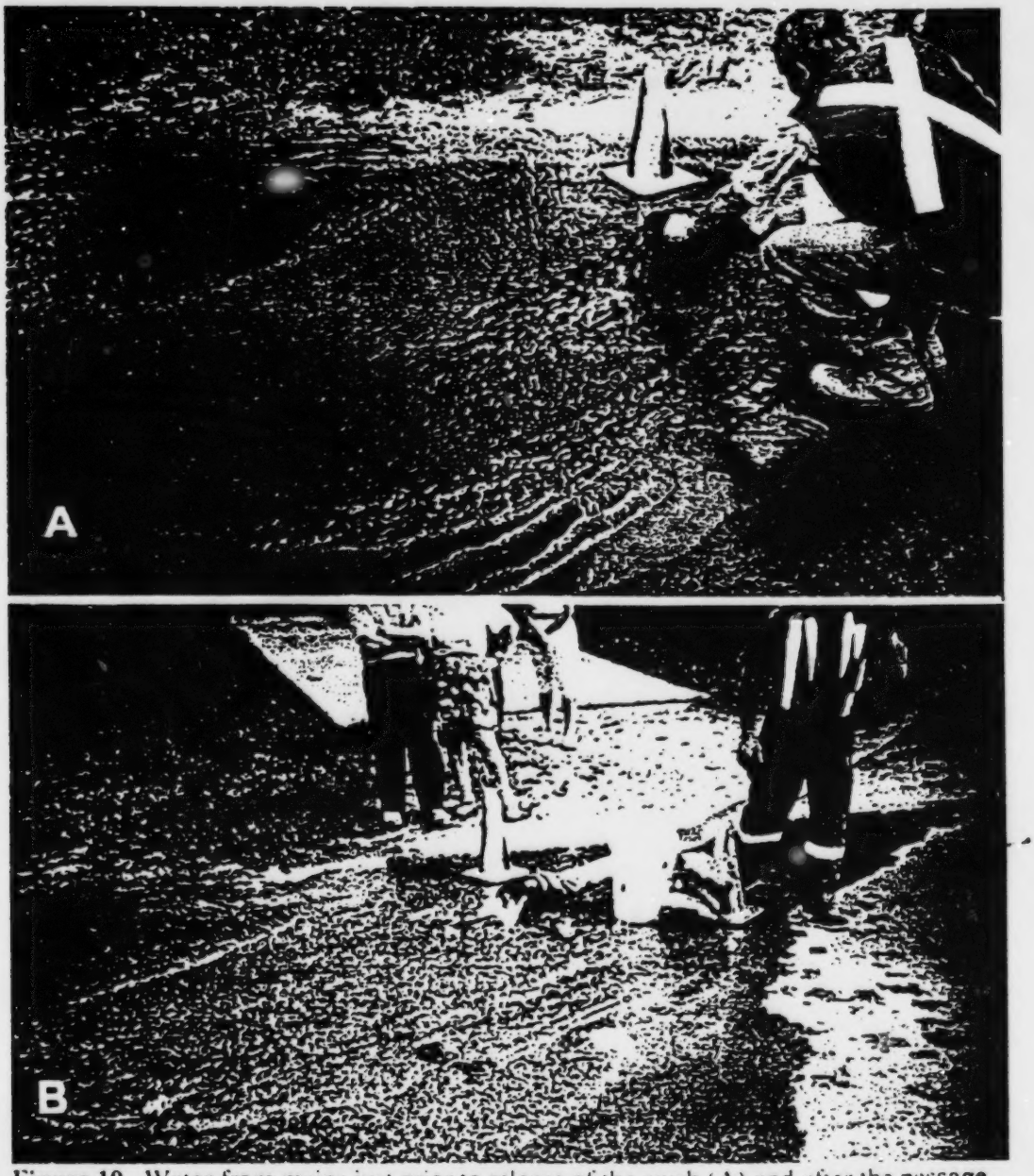

Figure 10. Water from mains just prior to release of the swab (A) and after the passage of the swab out of the main (B).

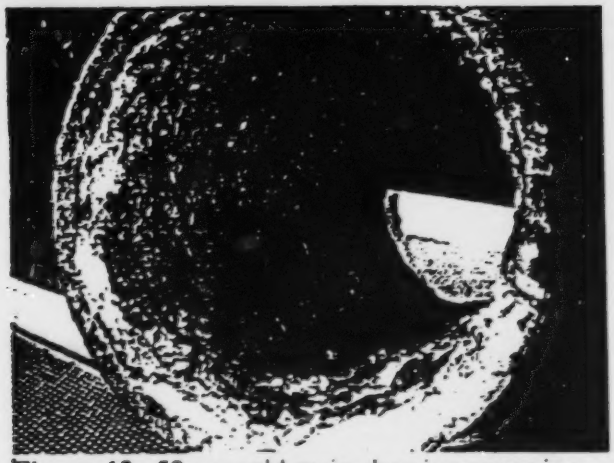

Figure 12. 50 year old main showing extensive biofilm formation.

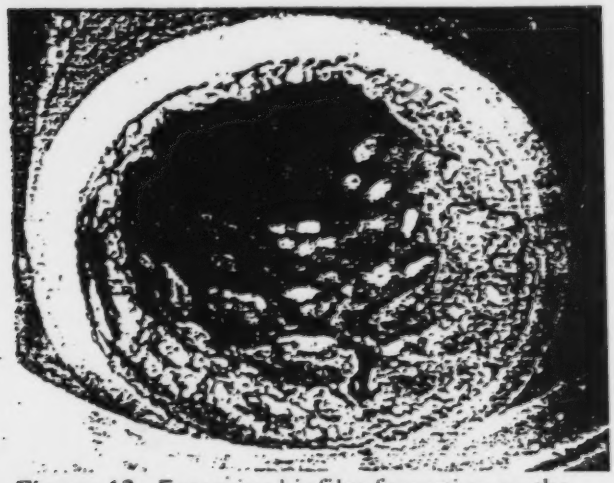

Figure 13. Extensive biofilm formation on the inside of a 1.25 inch copper line.

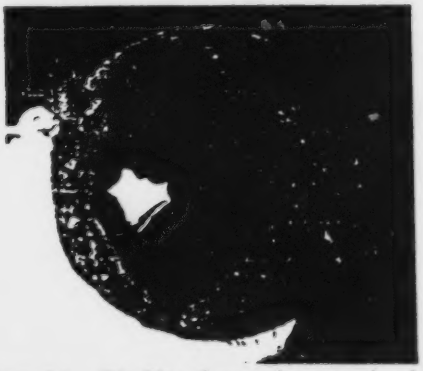

Figure 14. Biofilm formation on the inside of a 6 inch cast iron main.

Results of the microscopic examination of pipe biofilm are in Table 5. Most pipes contained primarily *Leptothrix* cells, with lesser amounts of *Gallionella*. Both *Leptothrix* and *Gallionella* are iron-oxidizing bacteria (Figure 15). Only one sample contained predominantly *Gallionella*. Most samples also contained low levels of other types of bacteria (not iron-oxidizers). These bacteria were typically short to medium rods, found singly or in pairs. The only pipe that did not have bacterial biofilm was made of polyethylene.

Figure 15. Micrographs showing the presence of *Leptothrix* in biofilm samples.

Biofilm formation in pipes is a significant concern as pathogenic bacteria could adhere to biofilm and be protected from chlorine when the distributions pipes are disinfected. To understand the true significance of biofilm in the watermains of Walkerton, further studies were necessary. In discussing issues associated with pathogen survival following disinfection of the town mains with the Medical Officer of Health and OCWA, a biofilm study was commissioned. The study is on-going, and is described in the next section.

F. Biofilm Experiment

GAP EnviroMicrobial Services and OCWA initiated a study to determine the effects of current disinfection protocols of the Walkerton watermains. This study is still in progress, and will be written as a separate report. We will briefly describe the general principles and methods that are being used in the investigation.

The Medical Officer of Health for Walkerton expressed an interest in determining the effect of watermain disinfection protocols on the survival of introduced bacteria in the distribution system. Bacteria that are introduced into a distribution system may bind to particulate matter and biofilm that has accumulated in the pipes, and may be more resistant to disinfection protocols such as chlorination. In our study, we are attempting to mimic the contamination and disinfection protocols being used in Walkerton, to determine if they are sufficient to ensure complete removal from the system.

Very few studies have been done to investigate attachment and disinfection of bacteria in real systems. Most of these studies have been on a small scale using artificial systems. Results are conflicting, with some reporting that *E. coli* could grow in biofilm within the

distribution system (Block *et al.* 1997) and others showing that *E. coli* do not proliferate in biofilm and have limited survival in the distribution system (McMath and Holt 2000).

Table 5. Microscopic examination of pipe biofilm samples

Sample #	Date (d/m/y)	Description	Microscopic examination of biofilm
20986	17/07/00	Lead water service	Primarily *Leptothrix*
20987	17/07/00	Lead and copper service pipes	Primarily *Leptothrix*
20988	17/07/00	6 inch line to hydrant	Primarily *Leptothrix*
20989	17/07/00	Tubercule from 6 inch line	Primarily *Leptothrix*
21296	27/07/00	1.25 inch copper pipe	Primarily *Leptothrix*, some *Gallionella*. Few unattached (non-iron-oxidizing) bacteria. Lots of precipitated iron.
21297	27/07/00	Material flushed from 1.25 inch copper pipe.	Primarily *Leptothrix*, few *Gallionella*. Few unattached bacteria. Lots of precipitated iron.
21660	02/08/00	2 inch (I.D.) polyethylene pipe.	No bacteria detected, some precipitated iron.
21661	02/08/00	0.5 inch (I.D.) copper pipe	Primarily *Leptothrix*, heavily encrusted with iron. Some *Gallionella*, some free bacteria (short rods).
21662	02/08/00	0.5 inch (I.D.) copper service line	*Gallionella* – heavily encrusted with precipitated iron.
21663	02/08/00	0.75 inch (I.D.) galvanized steel service line.	Some Leptothrix and unattached bacteria.
21664	02/08/00	3.75 inch (I.D.) iron pipe	Heavily encrusted with primarily *Leptothrix*, some *Gallionella*.

In the experimental system devised by GAP EnviroMicrobial Services and OCWA, iron watermains were used that had been recovered from the Walkerton distribution system. These mains had extensive biofilm on the inner surface. These mains were run with water directly from well 5 to maintain as real a system as possible. Bacteria introduced into the water mains were *E. coli* (non-pathogenic), *E. coli* O157:H7 (verotoxin negative), and *Campylobacter jejuni*. The initial part of the investigation was to measure if the introduced bacteria would survive in the pre-established biofilm. Chlorination protocols were then performed on the pipes, including high level chlorination and swabbing.

The objectives of the research are as follows:

a) To determine if *E. coli*, *E. coli* 0157:H7, and *C. jejuni* are established in watermain biofilm.

b) To investigate the response of the three target bacteria to chlorination used by the town directly after the contamination event (2.5 to 5 mg/L free chlorine residual).

c) To assess the effectiveness of watermain swabbing followed by chlorination at 200 to 300 mg/L for 12 hours.

Outline of experimental method

On June 26, 2000, a section of old iron water main (4.9 metres long; 10 cm diameter) was removed from the Walkerton distribution system charged with water and both ends were immediately capped. On July 5, 2000, the water main pipe was cut into three 1.22 metre lengths and installed according to the experimental design (Figure 16). A piece of new iron pipe (cement lined) of equal length was also installed as the control or reference pipe. The 4th pipe in the system is not related directly to the bacterial experiment, but was installed to test a "Scale-free" technology. This technology is being used to investigate if it has potential to remove scale and biofilm from old distribution pipes.

During the experiment, water from the source well was pumped through each of the pipes at approximately 8 litres/min. The effluent from each pipe was passed through a series of stages to ensure that it was properly disinfected before release. The disinfection stages include filter units, UV disinfection, chlorination at 5 ppm, and dechlorination.

Figure 16. Biofilm experiment showing sections of water main and sampling ports.

Non-chlorinated well 5 water will be run through the pipe for a conditioning period before the introduction of bacteria. The three bacterial species will then be recirculated at low levels through the pipes for a short period of time. Following this, the pipe disinfection (chlorination) protocols will be used. At various time intervals, water and biofilm samples will be taken to assess bacterial numbers. Total bacterial populations will be assessed, along with *E. coli*, *E. coli* O157:H7 and *C. jejuni* numbers.

Findings from this experiment will confirm if the disinfection protocols used in the Walkerton distribution system were effective at eliminating pathogens from the watermains. The experiment is also important as it contributes to the general understanding of pathogen attachment and disinfection in biofilm systems. There is a lack of applied knowledge in this area, and it is hoped that further experiments will be performed following this study to investigate other aspects of pathogen survival and disinfection in water distribution systems.

SECTION IV – MATERIALS AND METHODS

METHOD A. SAMPLE COLLECTION AND PROCESSING

Solid samples such as soils and sediments in volumes of typically 100 to 500 g were taken aseptically using sterile scoops, and placed in sterile wide mouth sample jars. Water samples were typically collected in volumes of 500 to 1000 mL in sterile bottles using standard aseptic collection methods. Samples of distribution water were collected in bottles containing sodium thiosulphate to eliminate chlorine residual.

Sample bottles were immediately placed in a cooler containing ice packs, and returned to the laboratory within 1 to 2 days. Supporting documentation indicating in detail the site, nature and time of sampling was included. Upon receipt at the laboratory, the samples were logged, recorded and assigned laboratory identification numbers. Samples were then stored at 4°C, and analyzed within 48 h. Following analysis, samples were archived at 4°C.

METHOD B. TOTAL COLIFORM ISOLATION AND ENUMERATION

Membrane filtration

Liquid samples were passed through a 0.45 µm membrane filter by vacuum filtration. Solid samples (10 to 100 g) were resuspended in phosphate buffer and serially diluted before membrane filtration. Filters were then transferred onto mEndo agar LES (Difco), and incubated at 35°C for 20 to 24 hours. Colonies were counted that produced a greenish-gold metallic sheen. Results were reported as colony forming units (CFU) per 100 mL or per 100 g.

Most probable number analysis

In certain cases, soil samples were enumerated by most probable number analysis. Analysis was performed as in Method 9221 of the Standard Methods for Examination of Water and Wastewater (1998).

Presence / Absence analysis

The P-A test is a qualitative analysis that is a modification of method 9221.D, in Standard Methods for the Examination of Water and Wastewater (1998).

P-A broth contains lactose, a pH indicator (bromocresol purple) and chemicals to suppress the growth of non-target bacteria. One hundred mL of sample was added to 50 mL of triple strength P-A broth, and bottles were incubated at 35°C for 3 days. The production of acid (yellow colour) and/or gas indicates the presence of coliforms.

Total coliforms were confirmed by inoculating a positive P-A reaction into EC-MUG Broth (Difco) or by streaking an mEndo plate, and incubating at 35°C for 24h. Positive EC-MUG tubes showed growth and gas production. Positive mEndo plates showed

colonies with a gold, metallic sheen.

Confirmatory testing
Suspect colonies were isolated on nutrient gelatin yeast extract agar (Difco) and tested for oxidase and Gram-stain reactions. The API 20E and BIOLOG identification system were also used to confirm suspect colonies.

METHOD C. *ESCHERICHIA COLI* ENUMERATION

Membrane filtration
Liquid samples were passed through a 0.45 μm membrane filter by vacuum filtration. Solid samples (10 to 100 g) were resuspended in phosphate buffer before membrane filtration. Filters were then transferred onto mFC-BCIG agar (Difco), and incubated at 44.5°C for 20 to 24 hours. Colonies that produced a blue colour were counted. Results were reported as colony forming units per 100 mL or per 100 g. (Note: this method does not enumerate certain strains such as *E. coli* O157:H7. Please refer to methods section D for enumeration of this strain).

Most probable number analysis
In certain cases, soil samples were enumerated by most probable number analysis. Analysis was performed as in Method 9221 of the Standard Methods for Examination of Water and Wastewater (1998).

Presence / Absence analysis
P-A broth was inoculated and incubated as described above for the coliform bacteria.

Confirmation of *E. coli* was performed by inoculating a positive P-A reaction into EC-MUG Broth or streaking an mFC-BCIG plate, and incubated at 44.5°C. Positive EC-MUG tubes showed growth and gas production, and produced blue-white fluorescence under UV light (due to cleavage of methylumbiferyl-β-D-glucuronide). Positive mFC-BCIG plates showed the presence of blue colonies.

Confirmatory testing
Suspect colonies were isolated on nutrient gelatin yeast extract agar (Difco) and tested for oxidase and Gram-stain reactions. The API 20E or BIOLOG identification systems were also used to confirm suspect isolates.

METHOD D. *ESCHERICHIA COLI* O157:H7 DETECTION

Enrichment
Water and solid samples were enriched in P-A medium as described above. Water samples available in volumes larger than 100 mL were concentrated by membrane filtration before addition to P-A broth. On occasion, larger volumes of P-A medium were used for solid samples.

Inoculated P-A broth was incubated for 4 hours at 35°C to enable recovery of injured cells. The broth was then supplemented with novobiocin (Difco) at 20 mg/L (final concentration) and incubated for 1 to 3 days at 42°C. Following the appearance of acid and gas, samples were then processed using immunomagnetic separation.

Immunomagnetic separation

Immunomagnetic separation (IMS) uses magnetic beads coated with an antibody to *E. coli* O157:H7 (Dynabeads, Dynal USA). One mL of P-A broth was processed according to the manufacturer's instructions, and resuspended in 100 µL of buffer. Forty µL each of suspended particles was plated onto Sorbitol MacConkey agar (Oxoid) and Sorbitol MacConkey agar containing cefixime and potassium tellurite supplement (Oxoid). Plates were then incubated at 42°C for 24 or 48 hours.

The remaining 20 µl of beads were stored at -20°C for testing by PCR amplification.

Latex agglutination

Suspect colonies from Sorbitol MacConkey plates were tested by latex agglutination using the *E. coli* O157 DrySpot test kit (Oxoid). Latex agglutination uses an antibody detection method. Specific binding of antibodies to *E. coli* O157 cells will cause a clumping reaction.

Positive reactions were confirmed by testing Gram-stain and oxidase reactions. API 20E and BIOLOG detection systems and DNA testing were also performed.

Polymerase chain reaction (PCR) amplification

Detection and amplification of DNA using the polymerase chain reaction (PCR) is a powerful analytical tool for quickly and specifically replicating a target DNA fragment. This process is able to exponentially increase the number of target DNA fragments and create millions of copies in hours. If the target sequence is not present, no detectable amplification takes place.

We used a diagnostic PCR kit for the detection of *E. coli* O157:H7 (BAX *E. coli* O157:H7 Screening Kit, Qualicon, DuPont). This kit specifically targets *E. coli* O157:H7 and will not amplify bacteria other than this particular target strain. IMS beads stored at -20°C were tested by PCR amplification. Strains that were isolated following plating onto Sorbitol MacConkey agar were also tested using PCR analysis.

PCR amplification was done according the manufacturer's instructions. Detection of the amplified DNA was performed using agarose gel electrophoresis and staining with ethidium bromide. Results were photographed and scored for the presence of fluorescent bands in each lane.

A. Confirmatory testing

Presumptive *E. coli* O157:H7 isolates were sent to the central Ministry of Health Laboratory in Toronto for confirmation, verotoxin analysis, and genetic comparison

analysis by pulsed-field gel electrophoresis (PFGE). Isolates were also stored at in glycerol at -70°C.

METHOD E. *CLOSTRIDIUM PERFRINGENS* ENUMERATION

B. Membrane filtration

One litre of sample was passed through a 0.45 µm membrane filter by vacuum filtration. Filters were then transferred onto mCP agar (AccuMedia), and incubated under anaerobic conditions at 44.5°C for 20 to 24 hours. Most *C. perfringens* colonies are a distinctive mustard yellow colour. Suspect colonies are exposed to ammonium hydroxide fumes by inverting the plate over an ammonium hydroxide solution. *C. perfringens* colonies turn a magenta pink colour.

Colonies are further confirmed by inoculating freshly boiled Skim Milk broth (Difco) with the target colony, and incubating at 35°C for 24 hours. The presence of stormy fermentation (severe clotting of skim milk and excessive amounts of gas produced) indicates the presence of *C. perfringens*. Cultures can be further characterized by microscopic examination.

Results are reported as colony forming units per 1000 mL.

METHOD F. TOTAL AEROBIC SPORE-FORMER ENUMERATION

This method uses heat exposure (80°C for 10 minutes) to kill vegetative bacteria, leaving only viable spores. This temperature also activates the spores, allowing germination and growth on the culture media.

Water samples (1000 mL) were heated at 80°C for 10 minutes, and cooled on ice to room temperature. Five hundred mL of sample was then passed through a 0.45 µm membrane filter by vacuum filtration. Filters were transferred onto nutrient agar (Difco) with 2 g trypan blue/L, and incubated for 24 hours at 35°C. All of the bacterial colonies were counted, and results presented as colony forming units (CFU) per 500 mL.

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Table 2. Detection of total coliforms, *Escherichia coli* and *Escherichia coli* O157:H7 from environmental samples.

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
18728	28/05/00	A & L Labs(#145-001) - P/A bottle - well 5	enrichment	PRESENT	PRESENT	not detected
18729	28/05/00	A & L Labs(#145-001) ColiBlue plate, well 7 treated	plate	PRESENT	PRESENT	not detected
18734	29/05/00	Ditch water from Energizer outlet	water	<10	<10	
18735	29/05/00	Water running in ditch (Hwy 4)	water	400	<100	
18736	29/05/00	Surface soil in ditch opposite barn (Hwy 4)	soil	100,000	<100,000	
18737	29/05/00	Ditch water upstream of pipe (white) (Hwy 4)	water	20,000	<10,000	
18738	29/05/00	Water in ditch, location of white pipe (Hwy 4)	water	10,000	<10,000	
18739	29/05/00	Soil (60cm bsg) in ditch opposite barn (Hwy 4)	soil	200,000	<1,000	
18740	29/05/00	Flowing discharge from well 7	water	0	0	
18742	29/05/00	Soil sample below flowing discharge - well 7	soil	<100,000	<100,000	not detected
18743	29/05/00	Algal sample below well 7 discharge	algal mat	21,000	3,000	not detected
18744	29/05/00	Artesian well between well 6 and well 7	water	2	0	
18745	29/05/00	Swamp (flowing toward Well 7)	water	70,000	<10,000	not detected
18746	29/05/00	Drainage at well 6	water	400	<10	not detected
18747	29/05/00	Straw sample at well 6	water	<1,000	<1,000	
18748	29/05/00	Surface mud - opposite side of road (by well 6)	soil	1,600,000	100,000	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
18749	29/05/00	Well 6 - raw water	water	0	0	
18750	29/05/00	Running culvert 65m east of well 6	water	80	<10	
18751	29/05/00	Well 5 - raw water	water	24	21	
18752	30/05/00	Water from fire truck filled May 01/00	water	0	0	
18753	30/05/00	Apartment 11, 203 Archer St. cold tap	water	0	0	
18754	30/05/00	Apartment 11, 203 Archer St. hot tap	water	0	0	
18755	30/05/00	Apartment 3, 203 Archer St. hot tap	water	0	0	
18756	30/05/00	Park tap - from last site on end of lane	water	0	0	
18757	30/05/00	Surface drainage from Superior	water	110	10	not detected
18758	30/05/00	Upstream of drainage ditch & barn	water	4,000	<1000	
18759	30/05/00	Old hydrant - Wallace & Hwy 9 (Cl2 >2.2)	water	0	0	
18760	30/05/00	New hydrant below barn source	water	<10	<10	
18761	30/05/00	Standing water over valve for hydrant at Superior	water	<10	<10	
18762	30/05/00	[redacted] property - mud sample	soil	10,000	<10,000	not detected
18763	30/05/00	[redacted] property - manure sample	manure	390,000,000	300,000,000	not detected
18764	30/05/00	[redacted] Property - pond SW corner	water	170	260	not detected
18765	30/05/00	[redacted] property - pond sample near white cow	water	1,100	500	not detected
18766	30/05/00	409 Durham St.- water filled in bird bath (May 16)	water	0	0	
18767	30/05/00	[redacted] - 2 Third St. refrigerator water	water	3	5	not detected
18768	30/05/00	[redacted] - ice cubes (May 21)	water	<2	<2	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
18769	30/05/00	1203 Young St. (April 22 ice cubes)	water	<2	<2	not detected
18770	30/05/00	Overflow pipe from well 7 ([redacted]) May 28	water	insufficient volume for sample analysis		
18771	30/05/00	Saugeen Filter Supply - sprinkler system	water	<10	<10	
18772	26/05/00	COAL Sample - [redacted] office washroom	water	<2	<2	
18773	26/05/00	COAL Sample - new hydrant - water tower	water	<2	<2	
18774	27/05/00	COAL Sample - Energizer rrun-off	water	2	<2	not detected
18775	27/05/00	COAL Sample - Saugeen Filter - new hydrant	water	<2	<2	
18776	27/05/00	COAL Sample - Propane - new hydrant	water	<2	<2	
18777	27/05/00	COAL Sample - water tower - new hydrant	water	<2	<2	
18810	01/06/00	Upstream of cow-pie	water	400,000	<100,000	
18811	01/06/00	Downstream of cow-pie	water	70,000	<10,000	
18812	01/06/00	Swampy pool - center of pasture	water	60	20	
18813	02/06/00	Westside laneway - dog kennels	water	4,800	100	not detected
18814	02/06/00	Eastside laneway - dog kennels	water	4,000	500	
18815	02/06/00	Excavated pond near well 6 - west side	water	110	140	
18816	02/06/00	Excavated pond near well 6 - east side	water	60	70	not detected
18817	02/06/00	Pond near wrecking yard	water	25,000	450	
18818	02/06/00	Surface drainage near well 5 (30 meters)	water	8,000	<1,000	not detected
18819	02/06/00	Straw near well 5	solid	370,000	100,000	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
18820	02/06/00	Goose feces	solid	2,500,000,000	2,000,000,000	not detected
18821	02/06/00	Cow-pie (diffuse)	sludge	<1,000,000	7,000,000	not detected
18822	02/06/00	Cow-pie (diffuse)	sludge	72,000,000	59,000,000	not detected
18823	02/06/00	Southwest entrance of pasture	sludge	16,000,000	22,000,000	not detected
18903	05/06/00	Soil from 2nd hole - west of wellhouse 5	soil	3,300,000	1,400,000	not detected
18904	05/06/00	Straw pile 60 ft west of pumphouse 5	solid	15,000,000	<100,000	
18905	05/06/00	Algal mat from spring beside lane SE of well 5	algal mat	45,000	900	not detected
18906	05/06/00	Water from well 5	water	6	7	not detected
18907	05/06/00	Well 7 overflow	water	0	0	
18908	05/06/00	Water from spring along drive, east of well 5	water	47	14	not detected
18909	05/06/00	Water from spring near drive, east of well 6	water	600	80	not detected
18910	06/06/00	2 Mary St.	water	0	0	
18911	06/06/00	215 McNab unit #18 (apartment complex)	water	0	0	
18912	06/06/00	Short faucet (drinking), 311 Durham St. Apt 1	water	0	0	
18913	06/06/00	5 Valleyside Drive Apt. 405	water	0	0	
18992	08/06/00	east side of raft - pond adjacent to well 6	water	<10	<10	not detected
18993	08/06/00	west side of raft - pond adjacent to well 6	water	20	<10	not detected
18994	08/06/00	west end of pond - near well 6	water	30	<10	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
18995	08/06/00	surface - west end of pond - near well 6	water	<10	<10	not detected
18996	08/06/00	surface - centre of pond - near well 6	water	20	<10	not detected
18997	08/06/00	4" flex pipe discharging to NE side of pond	water	3 (overgrown)	165	**POSITIVE**
18998	08/06/00	Well 1 overflow	water	0	0	
18999	08/06/00	Well 1 treated water tap	water	0	0	
19000	08/06/00	test well 1 between wells 1 and 5	water	0	0	
19001	09/06/00	test well 1 between wells 1 and 5	water	0	0	
19002	08/06/00	test well 78' 5" SW of well 1 (water)	water	0	0	
19003	08/06/00	test well - 78' 5" SW of well 1 (leaf material)	solid	310,000	2,300	not detected
19090	13/06/00	well 5 raw water	water	3	8	not detected
19091	12/06/00	surface drain east of well 6 at laneway turn	water	90	110	not detected
19092	13/06/00	mud and scum on south side of drain (19091)	soil	900,000	110,000	not detected
19093	13/06/00	[redacted]202 Catherine St. water bottle	water	<2	<2	
19094	13/06/00	Surface slime off well casing from test well 1	solid	<1,000	<1,000	
19192	14/06/00	well 5 - scraping inside well casing	solid	448	4	not detected
19193	14/06/00	well 5 - turbine (swab)	swab	20	<10	
19194	14/06/00	well 5 - pump shaft 22' to 26' (swab)	swab	20	10	not detected
19195	14/06/00	water sample - well 5	water	<1,000	<1,000	not detected

* CFU = colony forming unit

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
19196	14/06/00	well 5 - swab	swab	absent	absent	
19397	20/06/00	swab - well 6 pump	swab	<10	<10	
19398	20/06/00	swab - well 6 pump shaft	swab	<10	<10	
19399	20/06/00	tubercules - pump well 6	solid	<10	<10	
19400	20/06/00	pump impellers - well 6	solid	<10	<10	
19401	19/06/00	well 5 - water from below 11.4m	water	1	0	not detected
19402	19/06/00	well 5 - water from middle zone	water	0	0	not detected
19403	19/06/00	well 5 - water from upper zone	water	<10	<10	not detected
19404	19/06/00	well 5 - water from upper zone	water	<10	<10	not detected
19405	19/06/00	well 5 - water from upper zone	water	2	0	not detected
19406	20/06/00	pond water - east side	water	2	2	not detected
19407	20/06/00	pond water - center	water	6	6	not detected
19408	20/06/00	pond water - west side	water	4	6	not detected
19409	19/06/00	control #1 - Elora and Durham	soil	300	<300	
19410	19/06/00	control #2 - wood lot south of MTO	soil	24,000	<300	
19411	19/06/00	control #3 - road east of Brant Diner.	soil	730	<300	
19412	19/06/00	soil #1 from the field beside well 5	soil	9,300	<300	
19413	19/06/00	soil #2 from the field beside well 5	soil	3,400	<300	
19414	19/06/00	soil #3 from field beside well 5	soil	1,500	<300	

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
19415	19/06/00	soil #4 from woods beside well 5	soil	2,800	910	not detected
19416	19/06/00	soil #5 from woods beside well 5	soil	200,000	20,000	not detected
19417	19/06/00	soil #6 from woods beside well 5	soil	15,000	360	not detected
19418	19/06/00	soil #7 from woods beside well 5	soil	4,000,000	3,000,000	not detected
19419	19/06/00	soil #8 from woods beside well 5	soil	46,000	360	not detected
19420	19/06/00	soil #9 from woods beside well 5	soil	7,500	<300	
19421	19/06/00	soil #10 from woods beside well 5	soil	1,100	<300	
19422	19/06/00	soil #11 from woods beside well 5	soil	110,000	<300	
19423	19/06/00	soil #12 from woods beside well 5	soil	4,300	2,300	not detected
19424	20/06/00	sediment #1 - pond (east side) by well 6	soil	2,300	2,300	not detected
19425	20/06/00	sediment #2 - pond (centre) by well 6	soil	<300	<300	not detected
19426	20/06/00	sediment #3 - pond (west side) by well 6	soil	730	730	not detected
19427	19/06/00	well 5 raw water	water	0.2	0.6	not detected
19528	22/06/00	[redacted] barn - sump beneath stairs	water	900	196	POSITIVE
19529	22/06/00	[redacted] barn - water trough	water	8	10	POSITIVE
19530	22/06/00	Well 6 - zone 7	water	0	0	
19545	16/06/00	west side of culvert on road to well 6	water	8,000	200	not detected
19546	15/06/00	[redacted] aspirator	water	absent	absent	

* CFU = colony forming unit

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
19937	26/06/00	well 6 - zones 5 and 6	water	0 (500 ml)	0 (500 ml)	not detected
19938	26/06/00	straw and debris 12' east between stakes 5 and 6	soil	7,000,000	77,000	not detected
19939	26/06/00	soil sample 12' east between stakes 5 and 7	soil	800,000	10,000	not detected
19940	26/06/00	straw and debris stakes 5 and 7	solid	4,000,000	1,700	not detected
19941	26/06/00	reversing stream sediment (by well 5)	water	100,000	10,000	not detected
19960	27/06/00	215 Princess - rusty water ([redacted])	water	<10	<10	
19961	27/06/00	215 Princess - clearing up ([redacted])	water	0	0	
19962	28/06/00	water bed at 8 Brown Ave.	water	0	0	
19963	28/06/00	well #6 - zone 1	water	0 (200 ml)	0 (200 ml)	not detected
19964	28/06/00	well #6 - zone 2	water	0 (200 ml)	0 (200 ml)	
19965	28/06/00	well #6 - zone 3	water	0 (200 ml)	0 (200 ml)	
19966	27/06/00	well #6 - zone 4	water	1	0 (200 ml)	
19967	27/06/00	soil near well 5 east of stake 5	soil	2,900,000	10,000	not detected
19968	27/06/00	soil near well 5 east of stakes 5 and 7	soil	200,000	<10,000	not detected
19969	28/06/00	soil near well 5 east of stake 7	soil	400,000	100,000	not detected
20015	30/06/00	culvert beside well 7	water	36	65	not detected
20016	30/06/00	spring between wells 6 and 7	water	6	0	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
20017	30/06/00	culvert closest to well 6	water	16	5	not detected
20018	30/06/00	culvert at bend near well 6	water	2	0	not detected
20019	30/06/00	pond beside well 6	water	<10	10	not detected
20020	30/06/00	culvert at laneway to Bright Hope kennels	water	10	10	
20021	29/06/00	well 3 at water line of first pump casing	swab	PRESENT	absent	not detected
20022	29/06/00	well 3 (below water line) bottom of first length	swab	PRESENT	absent	not detected
20023	29/06/00	well 3 inside 2nd length of pump casing	swab	PRESENT	absent	not detected
20024	29/06/00	well 3 - scraping from pump impeller area	solid	PRESENT	absent	not detected
20169	04/07/00	Silver creek - 104 Joseph	water	1,600	432	not detected
20170	04/07/00	private well - 104 Joseph	water	750,000	10	not detected
20172	04/07/00	[redacted] barn water trough	water	<2	<2	
20173	04/07/00	[redacted] barn sump	water	280	170	not detected
20174	04/07/00	valve feeding hose to sump	water	<2	<2	
20176	05/07/00	well 3 raw	water	0	0	
20240	06/07/00	well 3 zone 1 B2	water	0	0	
20241	06/07/00	well 3 zone 2 B2	water	0	0	
20248	06/07/00	Well 3 raw zone 3	water	0	0	

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
20345	09/07/00	830 Johnstone - basement at sink tap	water	absent	absent	
20346	09/07/00	ditch beside old RR track	water	PRESENT	PRESENT	not detected
20347	09/07/00	corner of Walker St. and Durham Rd.	water	absent	absent	
20673	13/07/00	Juice bottles - 605 Gibson St. (bottled Dec. 30/99)	water	0 (2 litres)	0 (2 litres)	not detected
20713	13/07/00	Energizer filter membrane - 365 litres filtered	filt. Water	absent	absent	not detected
20977	19/07/00	Well 7 - zone 3 at 232 feet	water	0	0	
20978	19/07/00	well 7 - zones 2 and 3 at 140 feet	water	0	0	
20979	19/07/00	well 7 - zones 1,2,3 at 381 feet.	water	0	0	
20980	19/07/00	kitchen sink from 521 Younge St.	water	<2	<2	
20981	19/07/00	bathroom sink from 521 Younge St.	water	<2	<2	
20982	20/07/00	Well 1 - zone 3 below 149 feet	water	0	0	
20983	20/07/00	Well 1 - zone 2 at 90-101 feet	water	<2	<2	
20984	20/07/00	Well 1 - zone 1 at 65-76 feet	water	<2	<2	
20985	20/07/00	water from biofilm - line 3 (well 5 raw water)	water	<2	<2	
21219	29/06/00	Straw (wet & dry) opposite west face of well 5	straw	PRESENT	PRESENT	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
21220	29/06/00	Straw (wet & dry) in line with south face of well 5	straw	PRESENT	PRESENT	not detected
21292	28/07/00	well 7 test well - zone 2	water	<2	<2	
21293	28/07/00	well 7 test well - zone 1	water	<2	<2	
21294	28/07/00	well 7 - raw water	water	<2	<2	
21298	27/07/00	cistern from 6 Centennial	water	122	2	negative
21299	27/07/00	well 7 test well - zone 2	water	<2	<2	
21516	31/07/00	213 Hinks - cold water tap	water	0	0	
21517	31/07/00	213 Hinks - hot water tap	water	0	0	
21518	31/07/00	well 5 raw water	water	360	0.4	
21786	08/08/00	well 5 raw water	water	53	1	
21869	09/08/00	well 8 - first flush	water	absent	absent	
21870	09/08/00	well 8 - 5 minutes after first flush	water	PRESENT	absent	
21949	15/08/00	well 5 raw	water	2.4	0.1	not detected
22024	16/08/00	upper pond (by well 6)	water	600	8	not detected

* CFU = colony forming unit

Table 2

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* (CFU* per 100 ml or CFU per 100 g)	*Escherichia coli* O157:H7 Detection
22025	16/08/00	lower pond (by well 6)	water	<100	2	not detected
22026	16/08/00	outlet to lower pond (by well 6)	water	6,000	28	not detected
22953	01/09/00	well 6 raw	water	2	0 (500 ml)	

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
19533	HH0069	23-Jun-00	108 McGivern Street	NA	NA	0 (CP)
19534	HH0070	23-Jun-00	105 McGivern	NA	NA	0 (CP)
19535	HH0071	23-Jun-00	83 Ridout	NA	NA	0 (CP)
19536	HH0074	23-Jun-00	104 McGivern Street	NA	NA	0 (CP)
19537	HH0075	23-Jun-00	61 McGivern Street	NA	NA	0 (CP)
19538	HH0076	23-Jun-00	53 McGivern Street	NA	NA	0 (CP)
19539	HH0077	23-Jun-00	305 Fraser Street	NA	NA	0 (CP)
19540	HH0078	23-Jun-00	40 McGivern Street	NA	NA	0 (CP)
19541	HH0079	23-Jun-00	36 McGivern Street	NA	NA	0 (CP)
19542	HH0080	23-Jun-00	22 McGivern Street	NA	NA	0 (CP)
19543	HH0081	23-Jun-00	12 McGivern Street	NA	NA	0 (CP)
19883	HH0082	26-Jun-00	19 Poplar Street	2.44	2.26	0
19884	HH0083	26-Jun-00	87 Griffith Street	2.06	2.80	3
19885	HH0084	26-Jun-00	12 Parkview	2.12	1.72	0
19886	HH0085	26-Jun-00	4 Parkview	1.14	0.88	0
19887	HH0086	26-Jun-00	2 Parkview	2.22	1.78	3
19888	HH0087	26-Jun-00	82 Griffith Street	2.54	2.60	0
19889	HH0088	26-Jun-00	91 Griffith Street	2.82	2.12	0
19890	HH0089	26-Jun-00	108 McGivern Street	3.28	2.40	0
19891	HH0090	26-Jun-00	16 Charlotte Street	3.52	2.84	5
19892	HH0091	26-Jun-00	9 Charlotte Street	3.12	2.88	0
19893	HH0092	26-Jun-00	5 First Street	2.12	0.57	256
19894	HH0093	26-Jun-00	7 Park Street	2.42	2.18	0
19895	HH0094	26-Jun-00	12 Park Street	2.00	2.20	0
19896	HH0095	26-Jun-00	3 Park Street	2.58	2.08	1
19897	HH0096	26-Jun-00	1001 Yonge Street	3.12	2.28	2

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
19898	HH0111	26-Jun-00	21 Ridout Street	0.66	0.56	1
19910	HH0097	27-Jun-00	1016 Yonge Street, Apt. 12	2.22	0.58	1
19911	HH0098	27-Jun-00	1016 Yonge Street, Apt. 2	1.90	1.68	0
19912	HH0099	27-Jun-00	1016 Yonge Street, Apt. 14	2.20	1.98	2
19913	HH0100	27-Jun-00	1018 Yonge Street	1.24	0.42	2
19914	HH0101	27-Jun-00	1020 Yonge Street, Apt. 1	3.16	2.60	3
19915	HH0102	27-Jun-00	1014 Yonge Street, Apt. 2	3.12	2.40	0
19916	HH0103	27-Jun-00	1014 Yonge Street, Apt. 3	3.40	3.62	100
19917	HH0104	27-Jun-00	1014 Yonge Street, Apt. 8,	3.74	2.92	19
19918	HH0105	27-Jun-00	1010 Yonge Street, Apt.1	2.46	2.12	79
19919	HH0106	27-Jun-00	1010 Yonge Street, Apt. 4	2.20	2.38	33
19920	HH0107	27-Jun-00	1010 Yonge Street, Apt. 5	2.38	1.54	8
19921	HH0108	27-Jun-00	1009 Yonge Street	3.12	1.54	23
19922	HH0109	27-Jun-00	Yonge Street - Subway (Restaurant)	3.00	3.00	12
19923	HH0110	27-Jun-00	Yonge Street - Medical Bldg. - [redacted]	3.34	2.00	5
19924	HH0112	27-Jun-00	30 Park Street	2.62	2.06	1
19925	HH0113	27-Jun-00	7 Third Street	3.62	2.94	0
19926	HH0114	27-Jun-00	9 Third Street	3.12	2.48	0
19927	HH0115	27-Jun-00	208 Warden Street	3.58	3.22	3
19928	HH0116	27-Jun-00	12 Second Street	3.34	3.10	3
19929	HH0117	27-Jun-00	13 Second Street	3.40	3.22	0
19930	HH0118	27-Jun-00	2 Parkview	3.16	2.86	2
19931	HH0119	27-Jun-00	4 Parkview	3.00	2.54	2
19932	HH0120	27-Jun-00	7 Second Street	3.56	2.70	1
19933	HH0121	27-Jun-00	6 Second Street	2.70	2.68	1
19934	HH0122	27-Jun-00	1201 Yonge Street	3.58	2.56	1

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
19935	HH0123	27-Jun-00	2 Third Street	3.54	3.10	2
19936	HH0124	27-Jun-00	12 Third Street	3.28	3.14	1
19949	HH0125	28-Jun-00	595 Warden Street - Brant Central School	3.30	2.70	6
19950	HH0126	28-Jun-00	1315 Yonge Street - Farm Credit Corp.	1.98	1.58	7
19951	HH0127	28-Jun-00	1304 Yonge Street - TD Bank	3.28	2.96	3
19952	HH0128	28-Jun-00	1200 Yonge Street	3.32	2.50	1
19953	HH0129	28-Jun-00	1106 Yonge Street - Funeral Home	3.18	3.14	0
19996	HH0130	29-Jun-00	206 Hinks Street	3.00	2.76	3
19997	HH0131	29-Jun-00	213 Hinks Street	3.32	2.28	1
19998	HH0132	29-Jun-00	15 Oriole Circle	>4.4	NA	3
19999	HH0133	29-Jun-00	11 Oriole Circle	0.26	0.08	4
20000	HH0134	29-Jun-00	7 Oriole Circle	NA	0.03	0
20001	HH0135	29-Jun-00	3 Oriole Circle	3.86	3.00	0
20025	HH0136	30-Jun-00	Well #7 Treated Water	NA	2.50	1
20026	HH0137	30-Jun-00	Well #7 Raw Water	NA	NA	0
20027	HH0138	30-Jun-00	Well #6 Raw Water	NA	2.00	5
20028	HH0139	30-Jun-00	Well #6 Treated Water (Not Swabbed)	NA	NA	OBS
20031	HH0140	30-Jun-00	20 Cunningham Street	NA	2.76	0
20032	HH0141	30-Jun-00	605 Yonge Street - Dist. System - Flushed	2.84	2.18	4
20033	HH0142	30-Jun-00	Yonge Street - Subway - Re-Sample	2.84	2.18	1
20034	HH0143	30-Jun-00	1010 Yonge Street, Apt. 1 - Re-Sample	2.66	1.54	0
20035	HH0144	30-Jun-00	1016 Yonge Street, Apt. 12 - Re-Sample	2.72	3.14	0
20036	HH0145	30-Jun-00	1016 Yonge Street, Apt. 14 - Re-Sample	2.86	2.86	2
20037	HH0146	30-Jun-00	218 Hinks Street	3.00	2.66	0
20038	HH0147	30-Jun-00	212 Hinks Street	2.84	2.64	1
20039	HH0148	30-Jun-00	205 Hinks Street	NA	NA	8

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20045	HH0157	4-Jul-00	331 South Street	2.98	1.42	0
20046	HH0158	4-Jul-00	410 Cayhey Street	3.02	2.70	2
20047	HH0159	4-Jul-00	Well # 7 Untreated	NA	NA	6
20048	HH0160	4-Jul-00	Well # 7 Treated Water	3.76	3.56	0
20049	HH0161	4-Jul-00	Well # 6 Raw Water	NA	NA	1
20050	HH0162	4-Jul-00	Well # 6 Treated Water	3.36	3.00	0
20151	HH0163	5-Jul-00	1 Ellen Avenue	3.22	1.92	1
20152	HH0164	5-Jul-00	140 Hinks Street	2.60	1.80	0
20153	HH0165	5-Jul-00	12 Mullen Drive	2.56	1.74	0
20154	HH0166	5-Jul-00	6 West River Road	3.04	1.78	0
20155	HH0167	5-Jul-00	5 Mullen Drive	3.00	2.78	0
20156	HH0168	5-Jul-00	11 Mullen Drive	3.20	2.20	0
20157	HH0169	5-Jul-00	125 Hinks Street, Apt. 205	3.24	2.72	0
20158	HH0170	5-Jul-00	125 Hinks Street, Apt. 103	3.20	2.80	0
20159	HH0171	5-Jul-00	125 Hinks Street, Apt. 302	3.12	2.84	0
20160	HH0172	5-Jul-00	5 Cedar Court	3.52	3.06	0
20161	HH0173	5-Jul-00	28 West River Road	3.36	2.76	0
20162	HH0174	5-Jul-00	18 West River Road	3.00	2.20	0
20163	HH0175	5-Jul-00	14 West River Road	2.84	2.22	1
20214	HH0176	6-Jul-00	Well #6 Raw Water	NA	NA	0
20215	HH0177	6-Jul-00	Well #6 Treated Water	1.80	2.30	1
20216	HH0178	6-Jul-00	Well #7 Raw Water	NA	NA	0
20217	HH0179	6-Jul-00	Well #7 Treated Water	2.68	3.26	0
20218	HH0180	6-Jul-00	20 Cunningham Road	2.46	2.76	0
20219	HH0181	6-Jul-00	Park Street - Walkerton PUC	2.60	2.52	0
20220	HH0182	6-Jul-00	5 West River Road	2.28	1.84	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20221	HH0183	6-Jul-00	13 West River Road	2.22	1.44	0
20222	HH0184	6-Jul-00	21 West River Road	2.44	2.32	0
20223	HH0185	6-Jul-00	39 West River Road	2.72	2.28	1
20224	HH0186	6-Jul-00	58 Ellen Avenue	2.86	2.42	0
20225	HH0187	6-Jul-00	42 Ellen Avenue	3.24	2.88	0
20226	HH0188	6-Jul-00	26 Ellen Avenue	2.98	2.66	1
20227	HH0189	6-Jul-00	125 Brown's Lane	1.26	0.10	0
20228	HH0190	6-Jul-00	121 Brown's Lane	1.21	0.63	1
20229	HH0191	6-Jul-00	111 Brown's Lane	1.78	1.52	0
20230	HH0192	6-Jul-00	106 Brown's Lane	3.48	3.16	0
20231	HH0193	6-Jul-00	24 Mullen Drive	2.70	2.18	1
20232	HH0194	6-Jul-00	4 Mullen Drive	2.34	1.02	0
20233	HH0195	6-Jul-00	133 Hinks Street	3.36	2.94	0
20250	HH0196	7-Jul-00	123 Brown's Lane	NA	NA	1
20251	HH0197	7-Jul-00	130 Brown's Lane	NA	NA	0
20252	HH0198	7-Jul-00	40 Johnstone Blvd.	NA	NA	1
20253	HH0199	7-Jul-00	34 Johnstone Blvd.	NA	NA	0
20255	HH0200	8-Jul-00	26 Johnstone Blvd.	2.34/2.40	1.42/0.86	1
20256	HH0201	8-Jul-00	16 Johnstone Blvd	2.34	2.02	11
20257	HH0202	8-Jul-00	24 Johnstone Blvd.	2.26	0.98	3
20258	HH0203	8-Jul-00	14 Johnston Blvd.	2.82	2.16	6
20259	HH0204	8-Jul-00	8 Johnstone Blvd.	2.94	2.50	10
20260	HH0205	8-Jul-00	9 Johnston Blvd.	3.00	3.73	7
20261	HH0206	8-Jul-00	2 Johnstone Blvd.	2.88	2.32	8
20262	HH0207	8-Jul-00	15 Johnstone Blvd.	2.70	1.72	7
20263	HH0208	8-Jul-00	27 Johnstone Blvd.	2.88	2.12	2

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20264	HH0209	8-Jul-00	33 Johnstone Blvd.	2.52	1.88	2
20265	HH0210	8-Jul-00	8 Elizabeth Street	2.26	1.58	4
20266	HH0211	8-Jul-00	3 Elizabeth Street	2.64	2.04	3
20267	HH0212	8-Jul-00	109 Hinks Street	3.22	2.26	5
20268	HH0213	8-Jul-00	112 Hinks Street	2.46	2.12	2
20269	HH0214	8-Jul-00	106 Hinks Street	2.96	2.18	2
20270	HH0215	8-Jul-00	100 Hinks Street	3.06	2.78	1
20298	HH0222	9-Jul-00	2 Elizabeth Street	2.58	2.52	4
20299	HH0223	9-Jul-00	9 Elizabeth Street	2.86	2.58	3
20300	HH0224	9-Jul-00	30 Johnstone Blvd.	2.9	2.88	3
20301	HH0225	9-Jul-00	610 McNab Street	2.94/2.52	2.56/2.66	1
20302	HH0216	9-Jul-00	605 Yonge Street (Audit)	3.48	2.70	4
20303	HH0217	9-Jul-00	Well 7 (Treated)	3.76/3.30	3.42/3.36	1
20304	HH0218	9-Jul-00	Well 7 (Raw)	NA	NA	31
20305	HH0219	9-Jul-00	Well 6 (Treated)	3.00	2.88	1
20306	HH0220	9-Jul-00	Well 6 (Raw)	NA	NA	3
20307	HH0221	9-Jul-00	325 South Street (Audit)	1.56	1.46	4
20308	HH0226	10-Jul-00	102 Kincardine Rd.	2.42	1.54	5
20309	HH0227	10-Jul-00	Hwy #4 & #9 (Mels Diner)	2.92	2.36	0
20310	HH0228	10-Jul-00	10 Circle Dr.	2.64	1.82	0
20311	HH0229	10-Jul-00	4 Circle Dr.	3.06	1.24	0
20312	HH0230	10-Jul-00	130 Kincardine Rd., Unit # 2	2.90	1.78	1
20313	HH0231	10-Jul-00	165 Kincardine Rd	0.00	0.04	1
20314	HH0232	10-Jul-00	131 Kincardine Rd	2.04	1.32	6
20315	HH0233	10-Jul-00	18 Industrial Rd	2.22	0.76	2
20316	HH0234	10-Jul-00	15 Industrial Rd.	2.82	2.42	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20317	HH0235	10-Jul-00	1 Industrial Rd.	2.94	2.16	171
20318	HH0236	10-Jul-00	Hwy #9 at Industrial Rd. (KFC)	2.84/3.02	2.30/2.32	3
20319	HH0237	10-Jul-00	Hwy #9 South of #4 (Petro-Can)	1.92	2.14/1.38	5
20320	HH0238	10-Jul-00	606 McNab Street	2.02	0.98/0.94	1
20321	HH0239	10-Jul-00	307 South Street	2.86	2.32	1
20322	HH0240	10-Jul-00	310 South Street	2.82/2.92	2.64	3
20377	HH0241	11-Jul-00	224 Kincardine Road	3.08	2.82	8
20378	HH0242	11-Jul-00	410 Cayley Street	2.94	1.78	2
20379	HH0243	11-Jul-00	Well # 6 Treated	2.16/2.02	2.12/1.00	3
20380	HH0244	11-Jul-00	Well # 6 Raw			3
20381	HH0245	11-Jul-00	Well # 7 Treated	3.16	2.18	0
20382	HH0246	11-Jul-00	Well # 7 Raw			0
20383	HH0247	11-Jul-00	505 Robinson Street	3.64	3.12	0
20384	HH0248	11-Jul-00	313 South Street	3.06	2.78	>2400
20385	HH0249	11-Jul-00	319 South Street	2.32	1.72	1
20386	HH0250	11-Jul-00	7 Lee Street	2.86	1.60	0
20387	HH0251	11-Jul-00	13 Lee Street	2.68	1.54	0
20388	HH0252	11-Jul-00	308 John Street, Apt # 106	3.12	2.60	0
20389	HH0253	11-Jul-00	308 John Street, Apt # 254	3.18	2.42	1
20390	HH0254	11-Jul-00	23 Oak Street	2.98	1.96	2
20391	HH0255	11-Jul-00	29 Oak Street	2.24	1.32	0
20392	HH0256	11-Jul-00	17 Lee Street	2.14	1.78	0
20393	HH0257	11-Jul-00	10 Coates Street	2.98	2.20	2
20394	HH0258	11-Jul-00	5 McGivern Street E.	3.40	3.12	1
20395	HH0259	11-Jul-00	6 McGivern Street E.	3.34	2.40	2
20396	HH0260	11-Jul-00	15 McGivern Street	2.96	2.30	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20397	HH0261	11-Jul-00	7 South Street, Apt # 5	3.68	2.70	0
20398	HH0262	11-Jul-00	16 Lee Street	2.72	2.38	0
20656	HH0263	12-Jul-00	1 McGivern Street E.	2.46	1.96	0
20657	HH0264	12-Jul-00	7 South Street, Apt # 3	2.82	2.10	0
20658	HH0265	12-Jul-00	7 South Street, Apt # 8	2.70	2.06	1
20659	HH0266	12-Jul-00	11 Lee Street	2.50	1.82	0
20660	HH0267	12-Jul-00	11 Miller Street	2.42	1.60	2
20661	HH0268	12-Jul-00	104 South Street	2.64	1.50	1
20662	HH0269	12-Jul-00	201 South Street	2.30	1.58	1
20663	HH0270	12-Jul-00	213 South Street	2.46	2.06	0
20664	HH0271	12-Jul-00	210 South Street	2.04	1.90	0
20665	HH0272	12-Jul-00	219 South Street	2.36	1.44	0
20666	HH0273	12-Jul-00	630 Gibson Street	2.36	1.68	0
20667	HH0274	12-Jul-00	514 Gibson Street	2.48	2.14	2
20668	HH0275	12-Jul-00	420 Gibson Street	2.42	1.96	0
20669	HH0276	12-Jul-00	410 Gibson Street			0
20670	HH0277	12-Jul-00	605 Gibson Street	3.74	2.06	0
20671	HH0278	12-Jul-00	521 Gibson Street	2.86	2.24	1
20672	HH0279	12-Jul-00	210 Prince Street	2.80	1.98	0
20680	HH0280	12-Jul-00	610 Gibson Street	.074/1.92	0.32/1.44	0
20681	HH0281	13-Jul-00	Well 7 Treated (Audit)	3.28	2.20	1
20682	HH0282	13-Jul-00	Well 7 Raw (Audit)			0
20683	HH0283	13-Jul-00	Well # 6 Treated (Audit)	0.14		21
20684	HH0285	13-Jul-00	2 Mary Street (Audit # 5)	2.78	2.06	0
20685	HH0286	13-Jul-00	605 Yonge Street (Audit#23)	2.36	2.24	0
20686	HH0287	13-Jul-00	165 Kincardine Rd.	0.12	0.04	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20687	HH0288	13-Jul-00	207 John Street	2.72	1.66	0
20688	HH0289	13-Jul-00	604 Victoria Street S.	2.94	2.12	1
20689	HH0290	13-Jul-00	616 Victoria Street S.	3.24	2.10	10
20690	HH0291	13-Jul-00	624 Victoria Street S.	2.92	1.66	0
20691	HH0292	13-Jul-00	512 Victoria Street S.	2.86	2.28	1
20692	HH0293	13-Jul-00	424 Victoria Street S.	2.90	2.06	0
20693	HH0294	13-Jul-00	208 Prince Street	2.34	2.04	0
20694	HH0295	13-Jul-00	505 Victoria Street S.	3.08	2.06	0
20676	HH0296	13-Jul-00	521 Victoria Street S.	3.00	1.56	0
20677	HH0297	13-Jul-00	605 Victoria Street S.	3.04	2.52	0
20678	HH0298	13-Jul-00	621 Victoria Street S.	3.12	2.92	7
20679	HH0299	13-Jul-00	638 Victoria Street S.	3.38	2.92	0
20729	HH0300	14-Jul-00	410 Gibson Street	2.62	2.18	2
20730	HH0301	14-Jul-00	216 Gibson Street	2.78	2.32	0
20731	HH0302	14-Jul-00	122 Gibson Street	2.78	2.02	0
20732	HH0303	14-Jul-00	107 Gibson Street	2.66	2.36	3
20733	HH0304	14-Jul-00	414 Cayley Street	2.70	2.64	1
20734	HH0305	14-Jul-00	315 Gibson Street	2.60	2.04	4
20735	HH0306	14-Jul-00	329 Gibson Street	1.98	1.28	5
20736	HH0307	14-Jul-00	407 Gibson Street	2.72	1.50	4
20737	HH0308	14-Jul-00	209 Prince Street	3.30	1.10	1
20738	HH0309	14-Jul-00	408 Victoria Street S.	2.42	1.02	2
20739	HH0310	14-Jul-00	334 Victoria Street S.	1.80	1.40	1
20740	HH0311	14-Jul-00	220 Victoria Street S.	2.86	1.48	0
20741	HH0312	14-Jul-00	215 Jane Street	2.54	1.72	2
20742	HH0313	14-Jul-00	401 Cayley Street , Apt # 108	2.54	1.98	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20743	HH0314	14-Jul-00	401 Cayley Street, Apt # 202	2.84	2.28	0
20744	HH0315	14-Jul-00	401 Cayley Street, Apt # 308	2.46	1.96	3
20745	HH0316	14-Jul-00	402 Cayley Street, Upper Apt.	2.84	1.84	3
20746	HH0317	14-Jul-00	106 Gibson Street	2.60	2.44	2
20747	HH0318	14-Jul-00	303 Jane Street	2.72	1.82	5
20748	HH0319	15-Jul-00	203 McNab Street, Apt # 403	2.00	1.58	3
20749	HH0320	15-Jul-00	203 McNab Street, Apt # 306	2.00	1.93	0
20750	HH0321	15-Jul-00	203 McNab Street, Apt # 305	2.18	1.34	0
20751	HH0322	15-Jul-00	215 McNab Street, Apt # 12	2.12	1.94	1
20752	HH0323	15-Jul-00	215 McNab Street, Apt # 7	2.30	1.58	4
20753	HH0324	15-Jul-00	215 McNab Street, Apt # 6	2.28	1.92	3
20754	HH0325	15-Jul-00	215 McNab Street, Apt # 2	2.20	1.46	2
20755	HH0326	15-Jul-00	505 Scott (Legion)	2.16	1.72	1
20756	HH0327	15-Jul-00	407 Jane Street	2.20	2.00	5
20757	HH0328	15-Jul-00	505 Jane Street	2.38	1.98	0
20758	HH0329	15-Jul-00	312 McNab Steet	2.06	1.48	4
20759	HH0330	15-Jul-00	408 Napier Street	2.22	1.62	3
20760	HH0331	15-Jul-00	320 Gibson Street	2.24	1.18	3
20761	HH0332	15-Jul-00	403 Jane Street	2.14	1.22	1
20762	HH0333	15-Jul-00	504 Napier Street	2.12	1.50	0
20763	HH0334	15-Jul-00	505 Napier Street	2.06	1.50	2
20764	HH0335	15-Jul-00	421 Robinson Street	1.90	1.72	0
20765	HH0336	15-Jul-00	409 Prince Street	2.06	1.86	0
20766	HH0337	15-Jul-00	401 Prince Street	2.18	1.86	4
20767	HH0338	15-Jul-00	402 Prince Street	2.28	1.42	1
20797	HH0339	16-Jul-00	Well # 7 (Raw)			1

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20798	HH0340	16-Jul-00	Well # 7 (Treated)	3.00	2.54	0
20799	HH0341	16-Jul-00	Well # 6 (Raw)			2
20800	HH0342	16-Jul-00	Well # 6 (Treated)	2.98	2.64	2
20801	HH0343	16-Jul-00	15 Industrial Road	2.48	1.68	0
20802	HH0344	16-Jul-00	37 Ridout Street	3.42	2.52	5
20803	HH0345	16-Jul-00	518 McNab Street	2.48	1.94	1
20804	HH0346	16-Jul-00	406 Prince Street	2.54	1.96	1
20805	HH0347	16-Jul-00	405 Prince Street	2.54	2.08	1
20806	HH0348	16-Jul-00	307 Prince Street	2.82	2.10	4
20807	HH0349	16-Jul-00	304 Prince Street	2.22	1.00	2
20808	HH0350	16-Jul-00	429 McNab Street	2.42	1.90	0
20809	HH0351	16-Jul-00	408 McNab Street	2.70	1.58	2
20810	HH0352	16-Jul-00	405 Napier Street	2.48	2.16	2
20811	HH0353	16-Jul-00	402 Napier Street	2.40	2.20	2
20812	HH0354	16-Jul-00	409 McNab Street	2.54	1.86	0
20813	HH0355	16-Jul-00	408 Jane Street	2.62	1.22	1
20814	HH0356	16-Jul-00	218 McNab Street	2.02	1.06	0
20815	HH0357	17-Jul-00	200 McNab Street., 1st Flr.	3.00	2.76	0
20816	HH0358	17-Jul-00	200 McNab Street., Suite 202	2.30	2.22	1
20817	HH0359	17-Jul-00	404 Jane Street	3.00	2.42	1
20818	HH0360	17-Jul-00	220 Princess Street	3.18	3.00	1
20819	HH0361	17-Jul-00	216 Princess Street	3.78	3.26	1
20820	HH0362	17-Jul-00	215 Princess Street	3.80	3.04	1
20821	HH0363	17-Jul-00	206 Princess Street	3.08	2.92	1
20822	HH0364	17-Jul-00	205 Princess Street	3.62	3.48	0
20823	HH0365	17-Jul-00	4 Watt Street	3.72	3.04	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20824	HH0366	17-Jul-00	7 Watt Street	3.90/4.10	3.26/3.48	1
20825	HH0367	17-Jul-00	23 Watt Street	0.76	0.70	2
20826	HH0368	17-Jul-00	10 Watt Street	0.44	0.16/0.18	0
20827	HH0369	17-Jul-00	715 Alma Street	3.14	2.78	0
20828	HH0370	17-Jul-00	704 Alma Street	3.38	3.14	0
20829	HH0371	17-Jul-00	202 Princess Street	3.18	2.90	1
20830	HH0372	17-Jul-00	107 Princess Street	3.46	2.88	1
20831	HH0373	17-Jul-00	9 Princess Street	3.20	2.96	3
20832	HH0374	17-Jul-00	610 Alma Street	3.88	2.12	2
20833	HH0375	17-Jul-00	603 Alma Street	2.58	1.76	0
20850	HH0376	18-Jul-00	Well # 7 Treated (Audit)	1.82	2.52	2
20851	HH0377	18-Jul-00	Well # 7 Raw (Audit)			0
20852	HH0378	18-Jul-00	Well # 6 Treated (Audit)	3.88	3.42	6
20853	HH0379	18-Jul-00	Well # 6 Raw (Audit)			3
20854	HH0380	18-Jul-00	108 Thomas Street (Audit #6)	2.70	2.50	1
20855	HH0381	18-Jul-00	37 Ridout Street (Audit #7)	2.62	2.60	1
20856	HH0382	18-Jul-00	212 Princess Street	2.18/0.12	2.00/0.00	0
20857	HH0383	18-Jul-00	705 Mary Street	2.06	2.02	1
20858	HH0384	18-Jul-00	706 Mary Street	2.22	2.10	6
20859	HH0385	18-Jul-00	713 Mary Street	2.28	1.86	2
20860	HH0386	18-Jul-00	1 Centennial Drive	2.84	2.38	3
20861	HH0387	18-Jul-00	7 Centennial Drive	2.94	2.66	1
20862	HH0388	18-Jul-00	720 Mary Street	2.62	2.60/0.92	5
20863	HH0389	18-Jul-00	809 Yonge Street	2.42	2.38	0
20864	HH0390	18-Jul-00	823 Yonge Street	2.64	2.48	1
20865	HH0391	18-Jul-00	833 Yonge Street	2.38	2.38	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20866	HH0392	18-Jul-00	810 Yonge Street	2.44	2.38	0
20867	HH0393	18-Jul-00	615 Colborne Street	2.46	2.34	0
20915	HH0394	19-Jul-00	629 Yonge Street	2.70	1.06	0
20916	HH0395	19-Jul-00	709 Yonge Street	2.26	1.42	2
20917	HH0396	19-Jul-00	616 Yonge Street	2.00	1.90	0
20918	HH0397	19-Jul-00	611 Yonge Street	3.06	2.48	1
20919	HH0398	19-Jul-00	604 Jackson Street, Apt # 1	3.04	2.24	0
20920	HH0399	19-Jul-00	604 Jackson Street, Apt # 2	2.54	2.18	0
20921	HH0400	19-Jul-00	410 Jackson Street	2.62	1.82	0
20922	HH0401	19-Jul-00	8 Centennial Drive	4.34	2.16	1
20923	HH0402	19-Jul-00	604 Colborne Street	2.60	2.54	0
20924	HH0403	19-Jul-00	518 Colborne Street	3.06	2.76	5
20925	HH0404	19-Jul-00	504 Colborne Street	2.08	1.42	0
20926	HH0405	19-Jul-00	519 Colborne Street	3.16	2.82	0
20927	HH0406	19-Jul-00	107 John Street	2.88	2.80	0
20928	HH0407	19-Jul-00	511 Colborne Steet, Apt # 1	3.40	2.96	0
20929	HH0408	19-Jul-00	107 Prince Street	3.18	2.78	0
20930	HH0409	19-Jul-00	417 Colborne Street	3.04	2.46	1
20931	HH0410	19-Jul-00	405 Colborne Street	3.28/0.2	3.06/0.10	0
20932	HH0411	19-Jul-00	624 Colborne Street, Apt # 2	2.94	2.72	1
20933	HH0412	19-Jul-00	407 Jackson Street	2.90	1.98	0
20934	HH0413	19-Jul-00	421 Jackson Street, Apt # 1	2.46	1.28	2
20935	HH0414	19-Jul-00	321 Jackson Street	2.68	2.02	0
20936	HH0415	19-Jul-00	307 Colborne Street	3.32	2.90	0
20937	HH0416	19-Jul-00	210 Colborne Street, Bottom Apt	3.08	2.94	0
20938	HH0417	19-Jul-00	124 Colborne Street	2.92	2.70	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20953	HH0418	20-Jul-00	Well # 7 Raw (Audit)			0
20954	HH0419	20-Jul-00	Well # 7 Treated (Audit)	3.74	2.80	0
20955	HH0420	20-Jul-00	Well # 6 Raw (Audit)			0
20956	HH0421	20-Jul-00	Well # 6 Treated (Audit)	3.64	2.70	0
20957	HH0422	20-Jul-00	20 Valleyside Drive (Audit # 22)	3.40	2.72	1
20958	HH0423	20-Jul-00	5 Marco Street (Audit # 26)	2.20	1.40	1
20959	HH0424	20-Jul-00	316 Jackson Street	2.24	2.06	0
20960	HH0425	20-Jul-00	304 Jackson Street, Apt # 6	2.88	2.46	0
20961	HH0426	20-Jul-00	110 Jackson Street	3.46	2.92	0
20962	HH0427	20-Jul-00	121 Jackson Street	2.68	2.48	1
20963	HH0428	20-Jul-00	130 Jackson Street, Upper Apt	2.98	2.72	0
20964	HH0429	20-Jul-00	209 Scott Street	3.76	3.62	0
20965	HH0430	20-Jul-00	208 Scott Street	1.98	1.20	0
20966	HH0431	20-Jul-00	115 Colborne Street	3.98	3.50	4
20967	HH0432	20-Jul-00	20 Colborne Street	3.34	3.14	3
20968	HH0433	20-Jul-00	308 Scott Street	2.42	2.04	0
20969	HH0434	20-Jul-00	414 Scott Street	3.28	3.18	0
20970	HH0435	20-Jul-00	409 Scott Street	3.38	3.14	0
20971	HH0436	20-Jul-00	309 Scott Street	2.18	1.84	0
20972	HH0437	20-Jul-00	204 Jane Street	3.24	3.08	1
20973	HH0438	20-Jul-00	119 Victoria Street	0.24	0.22	0
20974	HH0439	20-Jul-00	114 Victoria Street, Back Apt	3.42	3.18	0
20975	HH0440	20-Jul-00	105 Victoria Street, Apt # 2	3.30	3.06	0
20976	HH0441	20-Jul-00	106 Victoria Street	1.76	1.62	0
20991	HH0442	21-Jul-00	100 Scott Street	1.68	0.70	3
20992	HH0443	21-Jul-00	12 Colborne Street	3.14	2.86	2

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
20993	HH0444	21-Jul-00	11 Colborne Street	3.06	2.86	0
20994	HH0445	21-Jul-00	12 Jackson Street	2.84	2.78	2
20995	HH0446	21-Jul-00	15 Jackson Street	3.14	2.10	1
20996	HH0447	21-Jul-00	517 Yonge Street	2.46	1.68	1
20997	HH0448	21-Jul-00	3 Huron Street	3.50/2.04	3.42/2.66	0
20998	HH0449	21-Jul-00	4 Huron Street	3.30	3.22	2
20999	HH0450	21-Jul-00	506 Yonge Street	3.10	3.00	1
21000	HH0451	21-Jul-00	417 Yonge Street	3.02	2.34	5
21001	HH0452	21-Jul-00	412 Yonge Street	3.40	2.78	0
21002	HH0453	21-Jul-00	317 Yonge Street	3.16	2.88	1
21003	HH0454	21-Jul-00	305 Yonge Street	3.24	2.70	3
21004	HH0455	21-Jul-00	9 Joseph Street	3.40	2.98	1
21005	HH0456	21-Jul-00	104 Joseph Street	2.58	2.08	3
21006	HH0457	22-Jul-00	8 Jane Street	1.80	0.82	0
21007	HH0458	22-Jul-00	3 Jane Street, Lower Apt.	1.62	0.98	0
21008	HH0459	22-Jul-00	2 Jane Street	2.52	2.28	0
21009	HH0460	22-Jul-00	6 Amelia Steet, Apt # 1	1.50/1.24	0.58	2
21010	HH0461	22-Jul-00	205 Mary Street	1.00	0.38	2
21011	HH0462	22-Jul-00	204 Mary Street	1.68	1.34	1
21012	HH0463	22-Jul-00	8 Campbell Street	1.80	1.20	0
21013	HH0464	22-Jul-00	10 Mary Street	2.36	2.02	1
21014	HH0465	22-Jul-00	4 Mary Street	2.60	1.42	0
21015	HH0466	22-Jul-00	5 Mary Street	2.60	1.58	2
21016	HH0467	22-Jul-00	103 Mary Street, Apt # 2	2.14	2.02	1
21017	HH0468	22-Jul-00	511 Colborne Street, Apt # 1	1.78	1.42	1
21018	HH0469	22-Jul-00	110 Princess St.	2.14	1.34	1

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21019	HH0470	22-Jul-00	447 Alma Street	2.86	2.42	1
21020	HH0471	22-Jul-00	309 Alma Street	2.60	2.28	2
21021	HH0472	22-Jul-00	202 Joseph Street	3.02	2.14	2
21022	HH0473	22-Jul-00	203 Amelia Street	2.64	1.90	5
21036	HH0474	23-Jul-00	2 Mary Street (Audit # 5)	2.36	1.78	1200
21037	HH0475	23-Jul-00	605 Yonge Street (Audit # 23)	2.40	1.70	1
21038	HH0476	23-Jul-00	110 Amelia Street	2.12	1.36	1
21039	HH0477	23-Jul-00	107 Campbell Street	2.28	1.48	0
21040	HH0478	23-Jul-00	Well # 6 - Raw (Audit)	N/A	N/A	3
21041	HH0479	23-Jul-00	Well # 6 - Treated (Audit)	2.80	2.18	2
21042	HH0480	23-Jul-00	Well # 7 - Raw (Audit)	N/A	N/A	2
21043	HH0481	23-Jul-00	Well # 7 - Treated (Audit)	2.70	2.60	0
21044	HH0482	23-Jul-00	105 Alma Street	2.78	2.54	2
21045	HH0483	23-Jul-00	202 Campbell Street	3.12	2.62	0
21046	HH0484	23-Jul-00	206 Alma Street	2.52	1.76	1
21047	HH0485	23-Jul-00	203 Archy Street, Apt # 5	2.26/2.40	1.40/1.44	1
21048	HH0486	23-Jul-00	203 Archy Street, Apt # 9	2.30	1.70	0
21049	HH0487	23-Jul-00	409 May Street	2.66	2.06	0
21050	HH0488	23-Jul-00	404 May Street	3.08	2.06	0
21051	HH0489	23-Jul-00	401 May Street	2.76	2.16	0
21052	HH0490	23-Jul-00	305 May Street	1.86/1.40	0.98/0.40	0
21053	HH0491	23-Jul-00	211 Amelia Street	2.86	2.28	1
21054	HH0492	23-Jul-00	206 May Street	3.12	1.34	0
21055	HH0493	23-Jul-00	209 May Street	3.08	2.40	0
21056	HH0494	24-Jul-00	109 May Street	2.52	1.78	8
21057	HH0495	24-Jul-00	108 May Street	2.78	2.48	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21058	HH0496	24-Jul-00	102 May Street	2.64	2.12	1
21059	HH0497	24-Jul-00	113 May Street	2.90	2.20	2
21060	HH0498	24-Jul-00	4 May Street	2.06	1.88	0
21061	HH0499	24-Jul-00	1 May Street	1.78	1.54	0
21062	HH0500	24-Jul-00	5 May Street	2.14	1.46	0
21063	HH0501	24-Jul-00	300 Archy Street	2.76	2.06	4
21064	HH0502	24-Jul-00	120 William Street	2.38/4.40	0.98/3.58	0
21065	HH0503	24-Jul-00	103 William Street	2.56	0.94	1
21066	HH0504	24-Jul-00	121 William Street	2.26	1.32	1
21067	HH0505	24-Jul-00	132 William Street	2.80	1.62	3
21068	HH0506	24-Jul-00	6 Orange Street	2.88	1.58	1
21069	HH0507	24-Jul-00	15 Orange Street	2.68	1.46	1
21070	HH0508	24-Jul-00	106 Orange Street	1.34	0.80	0
21071	HH0509	24-Jul-00	6 Willow Street	2.48	1.98	0
21072	HH0510	24-Jul-00	209 Orange Street, Upper Apt.	3.54	2.54	0
21073	HH0511	24-Jul-00	13 George Street	1.46	0.96	0
21093	HH0512	25-Jul-00	Well # 6 (Treated)	3.00	2.74	0
21094	HH0513	25-Jul-00	Well # 6 (Raw)	N/A	N/A	2
21095	HH0514	25-Jul-00	Well # 7 (Treated)	3.76	2.90	1
21096	HH0515	25-Jul-00	Well # 7 (Raw)	N/A	N/A	0
21097	HH0516	25-Jul-00	5 Marco Street (Audit # 26)	2.30	1.90	1
21098	HH0517	25-Jul-00	60 Ellen Avenue (Audit # 15)	2.08	1.58	0
21099	HH0518	25-Jul-00	31 Willow Street	3.22	2.34	0
21100	HH0519	25-Jul-00	34 Willow Street	2.22	1.66	2
21101	HH0520	25-Jul-00	22 Willow Street	3.02	1.58	4
21102	HH0521	25-Jul-00	7 George Street	2.44	1.82	11

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21103	HH0522	25-Jul-00	10 George Street	2.12	1.92	4
21104	HH0523	25-Jul-00	920 Durham Road, Unit 30	3.04	1.42	5
21105	HH0524	25-Jul-00	920 Durham Road, Unit 27	3.16	1.46	7
21106	HH0529	25-Jul-00	204 Orange Street, Unit 20	1.96	0.60	2
21107	HH0530	25-Jul-00	204 Orange Street, Unit 16	1.76	0.64	0
21108	HH0531	25-Jul-00	204 Orange Street, Unit 36	2.90	0.76	0
21109	HH0532	25-Jul-00	204 Orange Street, Unit 39	3.10	1.42	8
21110	HH0533	25-Jul-00	204 Orange Street, Unit 1	2.72	2.04	13
21111	HH0534	25-Jul-00	204 Orange Street, Unit 6	3.38	2.74	1
21112	HH0535	25-Jul-00	35 Elm Street South	3.56	2.62	0
21113	HH0536	25-Jul-00	705 Durham Street	3.96	3.10	0
21114	HH0537	25-Jul-00	34 Elm Street	2.54	2.28	0
21115	HH0538	25-Jul-00	28 Elm Street	3.10	3.06	2
21116	HH0539	25-Jul-00	16 Elm Street	3.94	3.66	2
21167	HH0540	26-Jul-00	920 Durham Rd., Unit # 2	3.34	2.52	0
21168	HH0541	26-Jul-00	920 Durham Rd., Unit # 3	3.28	2.84	0
21169	HH0542	26-Jul-00	920 Durham Rd., Unit # 5	3.44	2.82	0
21170	HH0543	26-Jul-00	920 Durham Rd., Unit # 9	3.52	2.96	0
21171	HH0544	26-Jul-00	920 Durham Rd., Unit #14	3.54	3.38	0
21172	HH0545	26-Jul-00	920 Durham Rd., Unit # 18	3.40	3.22	0
21173	HH0546	26-Jul-00	920 Durham Rd., Unit # 20	3.36	2.52	0
21174	HH0547	26-Jul-00	920 Durham Rd., Laundry Bldg.	2.84	2.52	0
21175	HH0548	26-Jul-00	920 Durham Rd., Unit # 29	2.98	2.62	N/R
21176	HH0549	26-Jul-00	920 Durham Rd., Unit # 26	3.22	3.14	0
21177	HH0550	26-Jul-00	204 Orange, Unit # 32	3.12	1.36	0
21178	HH0551	26-Jul-00	204 Orange, Unit # 12	3.20	2.48	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21179	HH0552	26-Jul-00	204 Orange, Unit # 35	3.06	2.54	0
21180	HH0553	26-Jul-00	204 Orange, Unit # 24	3.38	3.12	0
21181	HH0554	26-Jul-00	204 Orange, Unit # 28	3.24	2.34	0
21182	HH0555	26-Jul-00	204 Orange, Unit # 8	2.96	2.54	0
21183	HH0556	26-Jul-00	20 George Street	3.14	2.44	0
21184	HH0557	26-Jul-00	712 Durham Rd.	2.90	2.36	0
21185	HH0558	26-Jul-00	6 Elm Street North	3.10	3.04	0
21186	HH0559	26-Jul-00	11 Elm Street North	2.84	1.36	2
21187	HH0560	26-Jul-00	914 Old Durham Rd.	2.66	2.42	2
21188	HH0561	26-Jul-00	905 Old Durham Rd.	2.80	2.48	1
21189	HH0562	26-Jul-00	120 Yonge Street (MOE Office)	2.80	1.36	0
21190	HH0563	26-Jul-00	3 Durham Street East	2.72	1.24	0
21191	HH0564	26-Jul-00	11 Yonge Street	2.58	1.04	1
21192	HH0565	26-Jul-00	12 Yonge Street	2.82	1.84	0
21193	HH0566	26-Jul-00	313 South Street (ReSample)	3.34	2.54	0
21194	HH0567	26-Jul-00	6 Scott Street	2.68	2.58	0
21195	HH0568	26-Jul-00	113 Yonge Street	2.78	2.54	1
21196	HH0569	26-Jul-00	235 Yonge Street	3.08	2.10	0
21225	HH0570	27-Jul-00	24 Cunningham Rd.	2.98	0.82	0
21226	HH0571	27-Jul-00	16 Cunningham Rd.	2.42	1.44	0
21227	HH0572	27-Jul-00	5 Cunningham Rd.	2.40	1.18	1
21228	HH0573	27-Jul-00	11 Duke Street	2.42	1.44	1
21229	HH0574	27-Jul-00	909 Old Durham Rd.	1.58	2.90	0
21230	HH0575	27-Jul-00	915 Old Durham Rd.	1.56	2.12	0
21231	HH0576	27-Jul-00	906 Old Durham Rd.	2.22	1.32	1
21232	HH0577	27-Jul-00	4 Elgin Street	2.76	1.32	1

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21233	HH0578	27-Jul-00	603Mary Street	2.00	1.40	0
21234	HH0579	27-Jul-00	606 Mary Street	2.02	1.00	1
21235	HH0580	27-Jul-00	107 Elgin Street	2.42	1.30	0
21236	HH0581	27-Jul-00	509 Alma Street	2.00	1.50	1
21237	HH0582	27-Jul-00	206 Elgin Street	1.90	1.10	0
21238	HH0583	27-Jul-00	205 Elgin Street	2.40	1.24	1
21239	HH0584	27-Jul-00	210 Elgin Street	2.12	1.22	1
21240	HH0585	27-Jul-00	219 Elgin Street	3.00	1.08	0
21262	**HH0560**	28-Jul-00	511 Maple Street	2.28	1.26	3
21263	**HH0561**	28-Jul-00	503 Maple Street	2.92	2.62	0
21264	**HH0562**	28-Jul-00	497 Maple Street	2.54	2.2	3
21265	**HH0563**	28-Jul-00	504 Maple Street	2.78	2.44	8
21266	**HH0564**	28-Jul-00	506 Alma Street	3.16	2.28	1
21267	**HH0565**	28-Jul-00	108 Huron Street	3.02	2.34	3
21268	**HH0566**	28-Jul-00	505 Mary Street	2.96	2.18	2
21269	**HH0567**	28-Jul-00	406 Mary Street	2.96	2.44	1
21270	**HH0568**	28-Jul-00	15 Maple Street - Main Office	2.96	1.86	0
21271	**HH0569**	28-Jul-00	15 Maple Street Unit 13	2.66	1.7	0
21272	**HH0570**	28-Jul-00	4 Charlotte Street, Unit # 1003	3.24	1.7	0
21273	**HH0571**	28-Jul-00	4 Charlotte Street, Unit # 2001	3.48	1.92	0
21274	**HH0572**	28-Jul-00	4 Charlotte Street, Unit # 102	2.94	3.16	0
21275	**HH0573**	28-Jul-00	4 Charlotte Street, Unit # 301	3.76	2.76	1
21276	**HH0574**	28-Jul-00	108 Archy Street	3.88	3.5	0
21277	**HH0575**	28-Jul-00	8 Maple Street	2.58	3.12	1
21278	HH0586	28-Jul-00	Well #6 - Raw (Audit)	N/A	2.48	3

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21279	HH0587	28-Jul-00	Well # 6 - Treated (Audit)	3.46	2.08	2
21280	HH0588	28-Jul-00	Well # 7 - Raw (Audit)	N/A	N/A	0
21281	HH0589	28-Jul-00	Well # 7 - Treated (Audit)	2.96	2.06	75
21282	HH0590	28-Jul-00	2 Mary Steet (ReSample & Audit)	2.48	2.1	0
21283	HH0591	28-Jul-00	60 Ellen Avenue (ReSample & Audit)	1.96	1	0
21284	HH0592	28-Jul-00	306 Durham Street West	3.34	2.88	0
21285	HH0593	28-Jul-00	290 Durham Street West	2.7	1.42	0
21286	HH0594	28-Jul-00	Durham Street West Agric. Bldg. # 2	3.16	2.98	4
21287	HH0595	28-Jul-00	15 Queen Street	3.12	1.76	0
21288	HH0596	28-Jul-00	7 Queen Street	2.82	1.48	5
21289	HH0597	28-Jul-00	20 Durham Street West	3.32	2.54	0
21290	HH0598	28-Jul-00	8 Durham Street West	3.26	3.04	0
21291	HH0599	28-Jul-00	8 Durham Street East	3.14	2.54	0
21300	HH0576	29-Jul-00	130 Durham Street East	3.48	3.04	2
21301	HH0577	29-Jul-00	122 Durham Street East	3.16	3.00	1
21302	HH0578	29-Jul-00	114 Durham Street East, Unit B	4.18	3.02	4
21303	HH0579	29-Jul-00	110 Durham Street East	3.26	2.94	2
21304	HH0580	29-Jul-00	104 Durham Street East, Upper Apt	3.80	2.88	2
21305	HH0581	29-Jul-00	101 Durham Street East	3.58	3.04	2
21306	HH0582	29-Jul-00	125 Durham Street East	3.30	2.42	1
21307	HH0583	29-Jul-00	20 Peter Street	3.36	2.56	0
21308	HH0584	29-Jul-00	108 Catherine Street	3.44	3.10	0
21309	HH0585	29-Jul-00	116 Catherine Street	3.22	3.04	0
21310	HH0586	29-Jul-00	15 Jackson Street, Upper Apt	2.54	2.26	0
21311	HH0587	29-Jul-00	16 Jackson Street, Apt # 5	3.68	3.24	1
21312	HH0588	29-Jul-00	206 Catherine Street	3.42	2.94	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21313	HH0589	29-Jul-00	214 Catherine Street, Apt 2	3.32	3.08	0
21314	HH0590	29-Jul-00	109 Colborne Street North	1.90	1.84	0
21315	HH0591	29-Jul-00	107 Colborne Street North	3.16	2.78	1
21316	HH0592	29-Jul-00	215 Catherine Street	3.60	3.33	4
21317	HH0593	29-Jul-00	7 Colborne Street	2.76	2.66	2
21318	HH0594	29-Jul-00	8 Colborne Street	3.48	3.28	0
21319	HH0595	29-Jul-00	11 Durham Street East	2.18	1.74	1
21330	HH0636	30-Jul-00	Well # 6 - Raw (Audit)	N/A	N/A	0
21331	HH0637	30-Jul-00	Well # 6 - Treated (Audit)	3.56	3.14	15
21332	HH0638	30-Jul-00	Well # 7 - Raw (Audit)	N/A	N/A	3
21333	HH0639	30-Jul-00	Well # 7 - Treated (Audit)	3.42	3.28	3
21334	HH0640	30-Jul-00	410 Cayley Street (Audit # 19)	2.54	2.48	0
21335	HH0641	30-Jul-00	34 Willow Street (Audit # 20)	2.62	2.48	5
21336	HH0642	30-Jul-00	29 Orange Street	0.92	0.70	2
21337	HH0643	30-Jul-00	47 Boulton Street	3.56	3.42	1
21338	HH0644	30-Jul-00	17 Cunningham Street	2.54	1.94	3
21339	HH0645	30-Jul-00	16 Bill Street	3.08	2.46	0
21340	HH0646	30-Jul-00	5 Bill Street	3.32	2.92	0
21341	HH0647	30-Jul-00	120 Ridout Street	3.32	3.10	0
21342	HH0648	30-Jul-00	116 Ridout Street	0.86	0.66	0
21343	HH0649	30-Jul-00	108 Ridout Street	2.42	1.88	2
21344	HH0650	30-Jul-00	202 Ridout Street	0.42	0.34	0
21345	HH0651	30-Jul-00	210 McGivern Street	3.30	3.00	0
21346	HH0652	30-Jul-00	212 McGivern Street	3.44	3.06	0
21347	HH0653	30-Jul-00	Corner of Ridout & McGivern Streets	3.44	3.02	0
21348 (CP)	HH0654	31-Jul-00	13 Bill Street	3.40	2.70	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21349	HH0655	31-Jul-00	P.U.C. end of Wallace	3.08	2.88	0
21350	HH0656	31-Jul-00	430 Durham Street East	1.54	1.44	0
21351	HH0657	31-Jul-00	420 Durham Street East	3.34	3.20	1
21352	HH0658	31-Jul-00	403 Durham Street East	3.18	3.02	0
21353	HH0659	31-Jul-00	402 Durham Street East	2.84	2.40	0
21354	HH0660	31-Jul-00	411 Durham Street East	3.30	1.52	1
21355	HH0661	31-Jul-00	413 Durham Street East, Apt # 1	3.48	1.54	0
21356	HH0662	31-Jul-00	419 Durham Street East	3.46	2.38	2
21357	HH0663	31-Jul-00	421 Durham Street East, East Apt	3.22	2.02	0
21358	HH0664	31-Jul-00	435 Durham Street East	2.64	2.38	0
21359	HH0665	31-Jul-00	15 McNab Street, Suite # 4	3.16	2.02	0
21498	HH0666	1-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	0
21499	HH0667	1-Aug-00	Well # 6 - Treated (Audit)	2.96	2.20	0
21500	HH0668	1-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	3
21501	HH0669	1-Aug-00	Well # 7 - Treated (Audit)	3.08	2.84	0
21502	HH0670	1-Aug-00	34 Willow Street (Audit)	2.44	2.14	2
21503	HH0671	1-Aug-00	12 Second Street	1.92	1.44	1
21504	HH0672	1-Aug-00	[redacted] RR# 4 Walkerton, Cty Rd. 4	3.22	2.98	1
21505	HH0673	1-Aug-00	220 Trillium Court	3.00	2.70	0
21506	HH0674	1-Aug-00	Brockton Works Wallace & Kincardine Road	2.92	2.30	0
21507	HH0675	1-Aug-00	219 Elgin Street	2.46	1.68	0
21508	HH0676	1-Aug-00	603 Mary Street	2.78	2.24	0
21509	HH0677	1-Aug-00	104 Durham Street, Upper Apt	3.12	2.32	0
21510	HH0678	1-Aug-00	Bruce Cty Hwy Dept Works	2.44	1.10	0
21511	HH0679	1-Aug-00	201 Durham Street West	2.78	1.70	0
21512	HH0680	1-Aug-00	111 Durham Street West	3.24	2.70	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21513	HH0681	1-Aug-00	11 Durham Street West	3.28	2.90	0
21514	HH0682	1-Aug-00	11 Durham Street East	2.80	2.62	1
21515	HH0683	1-Aug-00	101 Durham Street East	3.14	2.54	1
21572	HH0684	2-Aug-00	239 Durham Street East	2.72	2.70	1
21573	HH0685	2-Aug-00	1320 Yonge Street (Walkerton District H.S.)	2.26	1.14	4
21574	HH0686	2-Aug-00	450 Robinson Street (Sacred Heart H.S.)	2.28	1.32	2
21575	HH0687	2-Aug-00	223 Durham Street East (Home Hardware)	2.70	1.62	2
21576	HH0688	2-Aug-00	207 Durham Street East ([redacted])	2.94	2.58	0
21577	HH0689	2-Aug-00	249 Durham Street East (Walkerton Library)	2.92	1.92	1
21578	HH0690	2-Aug-00	307 Durham Street East (Temptations)	2.98	2.54	1
21579	HH0691	2-Aug-00	317 Durham Street East (T'Ks)	2.72	2.40	2
21580	HH0692	2-Aug-00	331 Durham Street East (Brown's Pharmacy)	3.26	3.02	1
21581	HH0693	2-Aug-00	347 Durham Street East (Creative Illusions)	3.36	2.62	0
21582	HH0694	2-Aug-00	31 Willow Street (ReSample)	2.66	1.82	0
21583	HH0695	2-Aug-00	102 Huron Street (Police Dept.)	2.86	2.24	1
21584	HH0696	2-Aug-00	403 Mary Street	2.54	2.36	0
21585	HH0697	2-Aug-00	203 Huron Street	3.10	1.76	0
21586	HH0698	2-Aug-00	209 Huron Street	3.10	2.64	1
21587	HH0699	2-Aug-00	210 Durham Street East	0.34	0.26	0
21588	HH0700	2-Aug-00	206 Durham Street East	3.00	1.32	1
21589	HH0701	2-Aug-00	216 Durham Street East	3.36	2.38	2
21590	HH0702	2-Aug-00	222 Durham Street East	3.30	2.52	3
21591	HH0703	2-Aug-00	222 Durham Street East, Apt A	3.40	2.44	2
21592	HH0704	2-Aug-00	232 Durham Street East	3.14	2.62	4
21593	HH0705	2-Aug-00	244 Durham Street East	3.16	2.36	0
21594	HH0706	2-Aug-00	302 Durham Street East	2.42	1.60	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21595	HH0707	2-Aug-00	320 Durham Street East	3.14	2.50	4
21596	HH0708	2-Aug-00	334 Durham Street East	3.36	2.22	0
21597	HH0709	2-Aug-00	348 Durham Street East	3.20	2.94	0
21598	HH0710	2-Aug-00	352 Durham Street East	3.36	2.84	0
21599	HH0711	2-Aug-00	206 Cayley Street, Apt # 2	3.10	2.14	1
21600	HH0712	2-Aug-00	202 Cayley Street (Softener on)	3.06	1.82	3
21601	HH0713	2-Aug-00	203 Cayley Street	2.88	2.30	1
21637	HH0714	3-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	38
21638	HH0715	3-Aug-00	Well # 6 - Treated (Audit)	2.92	2.92	1
21639	HH0716	3-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	1
21640	HH0717	3-Aug-00	Well # 7 - Treated (Audit)	2.64	2.32	0
21641	HH0718	3-Aug-00	15 Industrial Road	2.26	1.74	0
21642	HH0719	3-Aug-00	20 Cunningham Road	2.60	1.40	1
21643	HH0720	3-Aug-00	10 McNab Street	3.12	2.76	2
21644	HH0721	3-Aug-00	109 Scott Street	2.72	2.04	0
21645	HH0722	3-Aug-00	108 Cayley Street	2.72	2.14	0
21646	HH0723	3-Aug-00	21 Peter Street	3.44	3.06	1
21647	HH0724	3-Aug-00	13 Peter Street	3.46	2.94	3
21648	HH0725	3-Aug-00	99 Durham Street East	3.14	3.06	39
21649	HH0726	3-Aug-00	4 Colborne Street	3.34	2.98	0
21650	HH0727	3-Aug-00	106 Campbell Street	3.36	3.02	0
21651	HH0728	3-Aug-00	111 Mary Street	2.18	1.88	0
21652	HH0729	3-Aug-00	107 Archy Street	3.42	2.98	3
21653	HH0730	3-Aug-00	5 Archy Street, Apt # 1	3.52	2.80	0
21654	HH0731	3-Aug-00	104 Amelia Street	2.86	1.66	1
21655	HH0732	3-Aug-00	204 Amelia Street	2.88	2.42	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21656	HH0733	3-Aug-00	402 Campbell Street	3.24	2.52	0
21665	HH0734	4-Aug-00	12 Victoria Street North	3.20	2.08	0
21666	HH0735	4-Aug-00	18 Victoria Street North	3.02	2.52	1
21667	HH0736	4-Aug-00	106 Colborne Street North	1.66	1.28	0
21668	HH0737	4-Aug-00	12 Queen Street	2.10	1.80	0
21669	HH0738	4-Aug-00	5 Valleyside Drive, Unit # 102	3.36	2.68	0
21670	HH0739	4-Aug-00	5 Valleyside Drive, Unit # 209	3.22	2.60	0
21671	HH0740	4-Aug-00	5 Valleyside Drive, Unit # 303	3.28	2.84	0
21672	HH0741	4-Aug-00	5 Valleyside Drive, Unit # 410	2.86	2.40	0
21673	HH0742	4-Aug-00	14 Karin Crescent	3.40	3.34	0
21674	HH0743	4-Aug-00	18 Karin Crescent	2.96	2.72	0
21675	HH0744	4-Aug-00	23 Karin Crescent	2.86	2.40	0
21676	HH0745	4-Aug-00	203 Campbell Street	2.02	1.58	0
21677	HH0746	4-Aug-00	37 Karin Crescent	3.70	2.88	0
21678	HH0747	4-Aug-00	17 Karin Crescent	3.60	3.40	0
21679	HH0748	5-Aug-00	45 Karin Crescent	2.04	1.94	0
21680	HH0749	5-Aug-00	51 Karin Crescent	2.34	1.92	0
21681	HH0750	5-Aug-00	26 Karin Crescent	2.68	2.02	0
21682	HH0751	5-Aug-00	10 Karin Crescent	2.50	2.38	2
21683	HH0752	5-Aug-00	27 Karin Crescent	2.70	2.48	0
21684	HH0753	5-Aug-00	6 Karin Crescent	3.10	2.30	0
21685	HH0754	5-Aug-00	3 Karin Crescent	3.26	3.06	1
21686	HH0755	5-Aug-00	45 Valleyside Drive	3.14	2.20	0
21687	HH0756	5-Aug-00	42 Valleyside Drive	3.12	2.30	1
21688	HH0757	5-Aug-00	34 Valleyside Drive	3.28	2.42	0
21689	HH0758	5-Aug-00	24 Valleyside Drive	2.72	2.20	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)

* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21690	HH0759	5-Aug-00	25 Valleyside Drive	3.34	2.84	0
21691	HH0760	5-Aug-00	7 Sepp Court	2.24	1.86	0
21692	HH0761	5-Aug-00	23 Valleyside Drive	1.38/1.36	1.08/0.72	0
21693	HH0762	5-Aug-00	120 Yonge Street North	3.12	2.34	0
21694	HH0763	5-Aug-00	108 Yonge Street North	2.86	2.16	0
21695	HH0764	5-Aug-00	39 Yonge Street North	2.70	2.24	0
21696	HH0765	5-Aug-00	33 Yonge Street North	2.58	1.86	0
21697	HH0766	6-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	4
21698	HH0767	6-Aug-00	Well # 6 - Treated (Audit)	2.76	2.18	7
21699	HH0768	6-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	1
21700	HH0769	6-Aug-00	Well # 7 - Treated (Audit)	3.40	2.48	3
21701	HH0770	6-Aug-00	108 Thomas Street (Audit # 6)	2.16	1.74	0
21702	HH0771	6-Aug-00	21 Watt Street (Audit # 25)	2.46	1.38	1
21703	HH0772	6-Aug-00	26 Yonge Street North	2.90	2.60	3
21704	HH0773	6-Aug-00	23 Yonge Street North	2.54	2.20	2
21705	HH0774	6-Aug-00	20 Valleyside Drive	3.36	2.54	0
21706	HH0775	6-Aug-00	127 Yonge Street	2.42	2.02	0
21707	HH0776	6-Aug-00	8 Bill Street	3.00	2.72	0
21708	HH0777	6-Aug-00	503 Alma Street	2.72	2.32	0
21709	HH0778	6-Aug-00	6 Joseph Street	2.34	1.50	1
21741	HH0779	7-Aug-00	719 Durham Street East	2.84	1.96	2
21742	HH0780	7-Aug-00	925 Old Durham Road	2.44	2.12	0
21743	HH0781	7-Aug-00	13 Cunningham Road	2.84	2.42	0
21744	HH0782	7-Aug-00	102 Elgin Street	2.54	2.08	0
21745	HH0783	7-Aug-00	203 Joseph Street	2.78	2.08	1
21746	HH0784	7-Aug-00	208 Joseph Street	2.86	1.90	4

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21747	HH0785	7-Aug-00	420 Alma Street	2.38	1.82	3
21748	HH0786	7-Aug-00	211 Jackson Street	2.80	2.76	0
21749	HH0787	7-Aug-00	219 Jackson Street	2.72	1.86	1
21750	HH0788	7-Aug-00	235 Jackson Street	2.82	2.28	1
21751	HH0789	7-Aug-00	107 Cayley Street	2.68	2.50	0
21752	HH0790	7-Aug-00	3 Cayley Street, Unit # 1	2.82	1.90	2
21753	HH0791	7-Aug-00	315 Colborne Street	3.24	2.76	1
21754	HH0792	7-Aug-00	105 Amelia Street	2.92	2.12	1
21755	HH0793	7-Aug-00	26 McGivern Street	3.00	2.66	0
21756	HH0794	8-Aug-00	22 Oriole Circle (Audit # 14)	1.80/1.59	1.34/1.87	2
21757	HH0795	8-Aug-00	60 Ellen Ave - (Audit # 15)	1.78	1.74	0
21758	HH0796	8-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	2
21759	HH0797	8-Aug-00	Well # 7 - Treated (Audit)	3.12	2.94	0
21760	HH0798	8-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	0
21761	HH0799	8-Aug-00	Well # 6 - Treated (Audit)	N/A	N/A	2
21874	HH0800	11-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	0
21875	HH0801	11-Aug-00	Well # 6 - Treated (Audit)	N/A	N/A	12
21876	HH0802	11-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	3
21877	HH0803	11-Aug-00	Well # 7 - Treated (Audit)	N/A	N/A	3
21878	HH0804	11-Aug-00	331 South Street (Audit # 17)	N/A	N/A	1
21879	HH0805	11-Aug-00	605 Yonge Street (Audit #23)	N/A	N/A	2
21898	HH0806	14-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	0
21899	HH0807	14-Aug-00	Well # 6 - Treated (Audit)	3.3	1.96	1
21900	HH0808	14-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	3
21901	HH0809	14-Aug-00	Well # 7 - Treated (Audit)	3.5	2.54	0
21902	HH0810 (CP)	14-Aug-00	410 Cayley Street	3.14	3.06	5

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 3. Distribution survey results of total aerobic spore-former enumeration.

Lab Number	Lab Number	Date Sampled	Location	Total chlorine (mg/L)	Free chlorine (mg/L)	Total aerobic sporeformers (CFU* per 500 mL)
21903	HH0811	14-Aug-00	224 Kincardine Hwy	2.92	1.24	1
21956	HH0812	16-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	0
21957	HH0813	16-Aug-00	Well # 6 - Treated (Audit)	3.2	2.24	1
21958	HH0814	16-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	0
21959	HH0815	16-Aug-00	Well # 7 - Treated (Audit)	2.44	1.82	0
21960	HH0816	16-Aug-00	37 Ridout Street	2.78	2.06	0
21961	HH0817	16-Aug-00	331 South Street	2.24	1.54/1.70	0
22091	HH0818	17-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	3
22092	HH0819	17-Aug-00	Well # 6 - Treated (Audit)	N/A	N/A	3
22093	HH0820	17-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	0
22094	HH0821	17-Aug-00	Well # 7 - Treated (Audit)	N/A	N/A	0
22095	HH0822	17-Aug-00	5 Marco Street	N/A	N/A	1
22096	HH0823	17-Aug-00	108 Thomas Street	N/A	N/A	0
22267	HH0824	21-Aug-00	Well # 6 - Raw (Audit)	N/A	N/A	2
22268	HH0825	21-Aug-00	Well # 6 - Treated (Audit)	N/A	N/A	1
22269	HH0826	21-Aug-00	Well # 7 - Raw (Audit)	N/A	N/A	1
22270	HH0827	21-Aug-00	Well # 7 - Treated (Audit)	N/A	N/A	1
22271	HH0828	21-Aug-00	20 Valleyside Drive	2.56	2.1	0
22272	HH0829	21-Aug-00	30 McGivern	2.58	1.92	0

(CP) - samples were analyzed for *Clostridium perfringens* (CFU per 1000 mL)
* CFU = colony forming unit

Table 4. Bacterial enumeration of hydrant and pipe samples (disinfection studies).

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms	*Escherichia coli*	*Escherichia coli* O157:H7 Detection
19531	22/06/00	corner of McNab and South St. hydrant #44	water	PRESENT	absent	**POSITIVE**
19532	22/06/00	Mullen and Brons Ave. hydrant #58	water	PRESENT	absent	not detected
19544	23/06/00	South St. behind high school (hydrant)	water	PRESENT	absent	
20002A	29/06/00	water main - 4" - tubercules inside pipe	solid	absent	absent	
20002B	29/06/00	water main - 4" - tubercules inside pipe	solid	absent	absent	
20002C	29/06/00	water main - 4" - tubercules inside pipe	solid	absent	absent	
20002D	29/06/00	water main - 4" - tubercules inside pipe	solid	PRESENT	absent	not detected
20002E	29/06/00	water main - 4" - tubercules inside pipe	solid	PRESENT	absent	not detected
20164	04/07/00	Durham and Jackson St. hydrant 15	water	absent	absent	
20165	04/07/00	Durham and Colborne hydrant 15	water	absent	absent	
20166	04/07/00	Durham and Colborne hydrant 15	water	absent	absent	
20167	04/07/00	Durham and Victoria hydrant 16	water	absent	absent	
20168	04/07/00	Durham and Victoria hydrant 16	water	absent	absent	
20175	05/07/00	water in 4" pipe for experiment	water	absent	absent	
20177	05/07/00	Elgin and Maple hydrant #156	water	absent	absent	
20178	05/07/00	Archer and Alma hydrant #163	water	absent	absent	
20179	05/07/00	Mary and Amellia hydrant #169	water	absent	absent	
20180	05/07/00	Mary and Amellia hydrant #169	water	absent	absent	
20238	06/07/00	Karin Crescent - short run - hydrant #10	water	absent	absent	
20239	06/07/00	Karin Crescent - long run - hydrant #10	water	absent	absent	
20242	06/07/00	control swab	swab	absent	absent	

Table 4

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms	*Escherichia coli*	*Escherichia coli* O157:H7 Detection
20243	06/07/00	Hawkins 11 swabing	water	absent	absent	
20244	06/07/00	Hawkins 13 swabing	water	absent	absent	
20245	06/07/00	Valleyside - hydrant #3	water	absent	absent	
20246	06/07/00	Sepp Court - hydrant #4	water	absent	absent	
20247	06/07/00	Valleyside new hydrant	water	absent	absent	
20294	08/07/00	Hwy 9 at Wallace - after swab	swab	absent	absent	
20295	08/07/00	Hwy 9 at Wallace - before swab	swab	absent	absent	
20296	08/07/00	Hwy 9 at Wallace - after clear	swab	absent	absent	
20337	07/07/00	Energizer south run	water	absent	absent	
20338	07/07/00	Energizer east - south run (before swab)	water	absent	absent	not detected
20339	08/07/00	corner of 4&9 and Wallace St. hydrant #187	water	absent	absent	
20340	08/07/00	behind BIG furniture hydrant 1	water	absent	absent	
20341	08/07/00	behind BIG furniture hydrant 2	water	absent	absent	
20342	08/07/00	behind BIG furniture hydrant 3	water	absent	absent	
20343	09/07/00	main line Victoria passed #2 tower to hydrant 10	water	absent	absent	
20344	09/07/00	Victoria hydrant 16 to corner of Walker and Durham	water	absent	absent	
20348	09/07/00	hydrant #95 Cunningham	water	absent	absent	
20349	09/07/00	hydrant #85 Willow	water	absent	absent	
20350	09/07/00	hydrant# 85 Willow	water	absent	absent	
20351	09/07/00	hydrant #86 Orange St.	water	absent	absent	
20714	13/07/00	wood chips from flushed/swabbed main ([redacted])	solid	PRESENT	PRESENT	not detected
20986	17/07/00	Lead water service, NW corner of McGivern and Ridout (83 Ridout St.)	scraping	microscopic (see Table 5)		
20987	17/07/00	lead and copper pipes from service line - to empty lot north of 83 Ridout St.	pipes	microscopic (see Table 5)		

Table 4

GAP Sample #	Date Collected d/m/y	Site description	Matrix	Total coliforms	*Escherichia coli*	*Escherichia coli* O157:H7 Detection
20988	18/07/00	6" line to 1953 hydrant replaced July 18 - west of Wallace St. opposite MTO yard, north of standpipe	scraping	microscopic (see Table 5)		
20989	18/07/00	Turburcule from above 6" line (sample 20988)	scraping	microscopic (see Table 5)		
20990	18/07/00	18" length of 6" line to hydrant (47 years old)	pipe	PRESENT	absent	not detected
21295	28/07/00	lead pipe from 6" cast iron main - used to feed school	pipe	microscopic (see Table 5)		
21296	27/07/00	1.25" copper pipe - Johnstone St. at Elizabeth (1/4" biofilm)	pipe	absent	absent	
21297	27/07/00	flushed material from above pipe (#21296)	water	absent	absent	
21659	02/08/00	1/2" copper at 505 Jane St.	water/sediment	absent	absent	
21660	02/08/00	2" polyethylene pipe - Jackson at Jane beside St.Paul's Church	pipe	absent	absent	not detected
21661	02/08/00	1/2" copper pipe - 505 Jane St. at McNab	pipe	absent	absent	not detected
21662	02/08/00	1/2" copper service line - 70 Ridout St.	pipe	absent	absent	not detected
21663	02/08/00	3/4" galvanized steel service line - 70 Ridout St.	pipe	absent	absent	not detected
21664	02/08/00	4"piece of 3.75"(ID) pipe ([redacted]) - 4 Colborn	pipe	absent	absent	not detected

Table 6. Daily rainfall precipitation data for the town of Walkerton.

Date	Rain (mm)
Up to April 20	43
May 1	3.3
May 9	38
May 12	20
May 13	50
May 18	38
May 24	15
May 25	3
June 1	17
June 11	25
June 13	22

Table 7. Historical Summary (October 1996 to April 2000) of Coliform and *E. coli* Detections in Walkerton Distribution System Water

Sampling Location	Number of Samples Taken	Coliform Detection		*E. coli* Detection	
		Positive Samples	Percent	Positive Samples	Percent
Well 5 Raw	116	13	11 %	1	<1 %
Well 5 Treated	115	8	7 %	1	<1 %
Well 6 Raw	25	3	12 %	0	0 %
Well 6 Treated	24	1	4 %	0	0 %
Well 7 Raw	98	3	3 %	0	0 %
Well 7 Treated	99	1	1 %	0	0 %
Distribution System	471	12	3 %	4	<1 %
Total	**948**	**41**	**4 %**	**6**	**<1 %**

Appendix 1. The Transport of Fecal Associated Microorganisms in Groundwater at Walkerton, Ontario using an *Escherichia coli* Tracer

The microbial impact of agricultural runoff on surface and groundwater is measured routinely by determining the concentrations of the fecal indicator bacteria: *Escherichia coli* and fecal streptococci; in the respective water matrix. However, to further elucidate how fecal wastes transport through surface and groundwater, biological tracers have been used by various researchers (Caldwell and Parr, 1937; Reneau and Pettry 1975; and Virauraghavan, 1978). The survival and distance traveled of bacterial, fungal, and viral pollutants are of utmost importance in being able to define the impacts of septic tank discharge and manure on a temporal and spatial basis.

By measuring surface water alone, there are often difficulties in determining if the fecal indicator is from the source being investigated or is from other sources. It is often crucial to determine the significance of the source in question, particularly if litigation is involved, and hence other contributing sources must be differentiated. To accomplish this, researchers have used microorganisms with specific characteristics such as biochemical markers. Hagedorn *et al.* (1978) reported the successful use of antibiotic-resistant strains of *Escherichia coli* and *Streptococcus faecalis* in monitoring the movement of subsurface water flow containing septage in one soil series in western Oregon. Rahe *et al.* (1978) McCoy and Hagedorn (1979, 1980), similarly studied the transport of fecal organisms using strains of antibiotic-resistant *E. coli* .

Results indicated that the *E. coli* tracer survived for periods of over 96 hours in soil and could be detected in groundwater for 2 to 3 weeks. Tracing the movement of chemical and biological contaminants has been conducted by various researchers using dyes such as rhodamine and fluorescein. However, in the case of microbiological pollutants, these same dyes failed to characterize the movement of the biological pollutants. Rahe (1979) conducted a study using a combination of fluorescein dye and an antibiotic-resistant *E. coli* to study the migration of the two different tracers at a site previously assessed for transport of septic tank wastes. The *E. coli* tracer was detected in the site piezometers after 1 hour of inoculation, while after a duration of 12 hours, the fluorescein tracer was not detected. This work raises serious concerns about the use of soluble chemical dyes to represent the migration of microbial particles in soil and groundwater. The dyes were most likely being adsorbed to clay and organic components in the soil and the particulates in the groundwater matrix.

As part of a five-year study on the effectiveness of artificial wetlands in treating municipal sewage conducted by the Ontario Ministry of the Environment, a residence time (RT) study was performed on two different wetland designs. A rectangular shaped wetland of cattails and a serpentine shaped wetland were compared as to their respective RT. Each marsh was of identical surface area. Initial flow through experiments were conducted using fluorescein dye with the result that the RT for the rectangular wetland was 6 days and for the serpentine design was approximately 6 days. Since bacterial reductions by the rectangular system were less than 5 percent and for the serpentine wetland were only 30 percent, an *E. coli* labeled with antibiotic resistance was tested as a

more appropriate tracer. Results clearly demonstrated that streaming of fecal associated microorganisms was occurring as the tracer *E. coli* was detected in 24 hours in the discharge of the rectangular design. In contrast, the tracer was detected in the discharge of the serpentine wetland in 96 hours.

In both cases, bacterial tracers exhibited a much faster transport through the different wetland designs than shown by the dye tracer. The study was described in the final report of the Listowel Marsh Study 1979-1984, Herskowitz 1986, and by Palmateer 1986.

The use of other bacterial tracers such as *Bacillus stearothermophilus* and H_2S-producing strains of *E. coli* were reported to migrate 920m in groundwater in New Zealand by Sinton, 1979. Tracer experiments were also conducted by injecting a mixture of antibiotic-resistant *E. coli* into a well site and monitoring their movement to other wells downstream. Another report by Pyle (1979), described an investigation of aquifer contamination using H_2S-positive *E. coli* and rhodamine WT dye as groundwater tracers. As in the previous reports, the *E. coli* movement was faster than the dye. The *E. coli* remained detectable for 1 month.

Streptococcus zymogenes was successfully used as a tracer in groundwater by Fournelle (1957). Movement of groundwater 15.2m was observed over a 70 day period. Marti *et al.* (1979) found differences in the rate of travel of various bacteria in an aquifer studied. *Streptococcus faecalis* traveled at a rate of 220 to 240 meters a day while *Bacillus subtilus* moved at a rate of 150 meters a day. These results suggest that tracer bacterium selected should be related to some degree with the target microbial pollutant.

The value of bacterial tracers to detect septic tank discharges to groundwater in areas of Karst topography has been demonstrated on several occasions in the area of Owen Sound, Ontario. Balkker and Palmateer (1995), investigated a site where 7 new private wells were constructed to provide potable water to homes in a small subdivision. Repeated attempts with fluorescein dye to determine the source were unsuccessful. The new wells continued to provide water containing *E. coli* , to their respective new homes.

The investigation commenced after the results of a most probable source study was reviewed. An *E. coli* resistant to 100 µg/mL nalidixic acid, an antibiotic rarely used, was introduced into a septic tank via a toilet at the suspected site of contamination. Testing of the contaminated wells commenced at 24 hour intervals for 2 weeks. The tracer *E. coli* was recovered from the first well in 48 hours, and continued to be recovered from other contaminated wells for several days thereafter.

In the follow-up investigation it was found, upon excavating the septic tank system that released the tracer *E. coli*, that during the installation of the septic tank, the plastic pipe connecting the home sanitary pipe to the septic tank had been ruptured. Raw human excrement, which was untreated, was leaching into the aquifer of the new wells.

The value of this *E. coli* tracer cannot be understated. The entire investigation was published in the Journal of Public Health Inspectors (1994).

The selection of this tracer bacterium which has been used in other studies (Palmateer *et al.*, 1983, 1989, and 1996.) was carefully performed. This nalidixic acid resistant strain was demonstrated to be plasmid free and carried no other antibiotic resistance. The origin of the resistance is chromosomal, and is therefore not susceptible to conjugational transfer of resistance factors to other bacteria.

Another possible mechanism of transfer of the resistance gene or genes is transformation. This process involves the uptake of a DNA fragment by a specific bacterial species although the ability of most bacteria is limited unless very special culture conditions are achieved where the recipient cells become competent. The maximum frequency for most antibiotic-resistant markers may be 0.1 to 1 percent of cells.

The other mechanism for DNA fragment uptake is by transduction, where a bacteriophage containing an antibiotic-resistant marker gene infects the host bacterium and transfers the resistant gene marker to the host bacterium's DNA. This process is termed transduction. Neither of the processes are recognized to occur frequently if ever in the environment but may occur to a limited extent in the intestine of animals and man.

Groundwater Transport Study - Walkerton, Ontario

The sources of contamination of the aquifer of Well # 5 may be fecal wastes originating from Farm X, however, the mechanism(s) of how the microbial component of these fecal wastes reached Well # 5 is unknown. Understanding the process of how surface contamination penetrated the soil overburden on Farm X or whether fecal waste was transported over the surface soils to reach areas in the immediate proximity of Well # 5 is paramount. This is crucial information if a sound and fundamental scientific explanation is to be provided to the public and to the many multi-disciplined public health professionals worldwide, who are following the account of the outbreak.

The tracer experiment is to be conducted by both G.A.P. EnviroMicrobial Services Inc. and Golder Associates, both of London, Ontario. Garry Palmateer (G.A.P. EnviroMicrobial Services Inc.) and Dan Brown (Golder Associates) will design the experiment with these primary objectives.

1. Introduction of a non-pathogenic strain of *E. coli* , labeled with nalidixic acid resistance, into a soil depression at a concentration similar to that in manure (i.e. 10^6 CFU/g). Bacteria will be introduced on the property or near the farm, and migration will be monitored through the soil horizons to the groundwater that appears to be part of an aquifer providing water to Well # 5.

2. Determine if the tracer *E. coli* can migrate, once reaching the groundwater to Well # 5, while the pump is operating at a representative rate to waste.

3. Samples of Well # 5 discharge water would be taken at a specific rate to determine quantitatively if the tracer *E. coli* has reached Well # 5. The survival time, distance travelled, (as measured at sites of recently installed test wells) and the amount of inoculum that would be required to provide the conditions to have resulted in *E. coli* O157:H7 in Well # 5 water throughout the distribution system, can be established.

This information is fundamental to understanding the conditions that altogether resulted in the outbreak.

It is also anticipated that comparable tracer experiments, conducted in a similar manner at Well # 6 and Well # 7 for the purpose of determining if surface water impacts the aquifers of these wells would be conducted.

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APPENDIX B

ACTION PLAN OF THE ONTARIO CLEAN WATER AGENCY

Supplemental Action Plan:
Restoring Safe Water to Walkerton

Date: May 29, 2000
Contact: Marc Ethier

This action plan is a supplement to the plan (attached) produced May 26 by the Municipality of Brockton.

1. Identification of Contamination Sources - to be completed June 2, 2000

- Work with others on site to identify all possible sources and ensure that each of these are investigated.
- Microbiologist (GAP) to review all analyses and to contribute to the authoritative determination of the source.
- Capture first flush of the overflow pipe from Well #7. A positive test for *E. coli* O157:H7 will be strong indication that the source of the contamination was through this overflow pipe. Consider all indications that this overflow pipe could have been the source of the contamination.
- Work with the private hydrogeologist and the MOE hydrogeologist to review all aspects of the aquifer and to report on the security of this source.
- If needed retain a reputable well company to provide advice and possible action for remedial work on wells. (International Water Supply)
- Produce comprehensive report on the investigation of sources and the actions taken to prevent a reoccurrence of the contamination.

2. Restoration of Potable Water - to be completed June 9, 2000

- Follow the Immediate Actions set out in the May 26th plan.
- Work with the other agencies to ensure the highest quality and a sufficient quantity of microbiological samples.
- Check for all parameters of water quality.
- Communicate results of testing to the public.
- Ensure appropriate dechlorination during all flushing.
- Once system is fully safe, work with others to ensure flushing and checking of each building.
- Work with Medical Officer of Health on the lifting of the boil water order.
- Full staffing 7 days a week until all required instrumentation is in place.
- Maintain documentation on the actions taken to restore potable water.

3. **Restoration of public confidence in the water supply - to be completed June 16, 2000**

- Provide public with a summary report on the source of the problem(s) and the actions taken to prevent a reoccurrence. Provide easy access to the comprehensive report on this topic.
- Install Outpost5 ™:
  - identify current status of analytical equipment including lab and field devices;
  - identify needs of equipment including field devices (e.g., chlorine residual meters on the treated discharge of each well, tubiduty meters, pH meters), Outpost5 ™ panels, software and hardware;
  - install panels to existing pump stations and water towers; and
  - configuration and integration of Outpost5 ™ to field devices and SCADA.
- Integration for internet site to allow public in Walkerton to access real-time data on chlorine residuals, temperature, turbidity, pH.
- Provide regular updates to the public (daily then weekly) on sample results and actions being taken. Updates on the Walkerton web site and on hard copy at the public library and at the PUC Office.
- Consider the value of town hall meeting(s), one prior to the time of the lifting of the boil water advisory and a second one to introduce the information on the web site.

4. **Follow-ups**

- Continuous monitoring of operations and chlorine residuals.
- Close continuous communication with MOH, MOE.
- Capital improvements to ensure sufficient contact time (15 minutes) for effective disinfection.
- Consider conversion from chlorine gas to sodium hypochlorite.

NOTE: The dates detailed in this Action Plan were not achieved due to the significant increase in the work required to remediate the system.

00086
May 24, 2000
Rev. May 26, 2000

MUNICIPALITY OF BROCKTON
ACTION PLAN TO RESPOND TO
WALKERTON WATER SYSTEM CONTAMINATION

1.0 Immediate Actions

1.1 Ensure that overflow at Well No. 7 cannot backflow.

1.2 Increase chlorine dosages to achieve a residual of greater or equal to 2.0 mg/L in the distribution system

1.3 Unless demand conditions do not permit; (i.e. storage levels continue to decline), supply the system only from Well #6 and #7.

If necessary use Well #5.

1.4 Progressively flush the system moving away from the source(s).

1.5 Monitor chlorine residuals to ensure fresh water is being supplied to each flushed hydrant.

1.6 Do not flush simultaneously at more than 2 locations.

1.7 Ask customers to refrain from excess use.

1.8 Ensure that proper "boil water" notification is occurring.

1.9 Sample for TC/EC as follows.
- Daily until the MOE declares results are satisfactory.
- RW/TW at each operating source.
- A minimum of 10 consumer locations distributed throughout the distribution system.

1.10 Take measures (i.e. drive samples to lab) to ensure the fastest possible/practical turnaround time for lab results.

1.11 Subject to the lab results on source quality and considerations related to capacity begin to isolate parts of the distribution system (i.e. close valves so as to serve southwest from Well #5).

1.12 If necessary, repeat from 1.4.

1.13 When sample results are satisfactory, consult MOH re "Boil Water Order" removal.

2.0 Actions Within 5 Days

2.1 Identify possible contamination sources.

- Raw Water (aquifer)
- Pumphouses
- Reservoirs (i.e. vents)
- Distribution system – breaks/repairs
  new construction
- Other connected sources (i.e. wells)
- Flooded basements on May 12/00

2.2 Inspect all identified sources to ensure that they are not contributing contamination.

2.3 Subject to supply/demand considerations, isolate locations that may contribute contamination.

2.4 Develop an action plan to permenently secure locations that might contribute contamination.

2.5 Document all events including:

- Timeline of actions observed/taken
- Samples taken and results
- Flushing/disinfection procedures
- What went right
- What went wrong

3.0 Actions Within 10 Days

3.1 Identify and begin to implement (i.e. design and approvals) for any permanent solutions.

APPENDIX C

DESCRIPTION OF EQUIPMENT INSTALLED AND KEY QUALITY CONTROL CHECKS FOR STANDPIPES AND WELLS #5, #6 AND #7

Outpost5™

Outpost5™ is a comprehensive automated control and monitoring system designed to provide operations staff with the ability to control and monitor the Walkerton Water Supply and Distribution System to its maximum efficiency. Outpost5™ provides up-to-the-minute monitoring of the three well stations and the two standpipe water storage facilities that comprise the Walkerton system.

The basic Outpost5™ system is composed of a series of field units, each collecting data from its facility and each reporting to a central location where Outpost5™ software provides an effective operator interface, as well as a comprehensive set of data storage (up to five years) and analytical tools.

Components:

Units within the Outpost5™ System installed for the operation control and monitoring of the Walkerton Water Supply and Distribution System include:

- Pumping Station;
- Metering Station;
- Data Concentrator;
- Tower Repeater;
- Human Machine Interface (HMI); and
- Trending Screen.

For effective operation, each of the field units has an enclosure complete with its own continuous power supply and heater, and all the major components (such as processors and communications equipment) are designed to meet military specifications (-40°C to +70°C). Extensive surge suppression is included for both the power supply and communication media.

The following are brief descriptions of the aforementioned units and their relevance to the Walkerton Water Supply and Distribution System.

Pumping Station
Pumping Station units were installed at Well Houses #5, #6 and #7. The units are designed to handle up to 16, 120 VAC discrete inputs and 8, 4-20 mA analog inputs. This unit will monitor and control the water well stations. Of particular interest is the ability of this unit to receive information from the on-site automated chlorine residual analyzer, automated turbidity analyzer and flow meter. This equipment also receives a signal from the overflow monitor, which tells it if there is water in the overflow pipe when the pump at Well #7 is running. Start and stop pump control can be performed on site or by remote operation through the Outpost5™ HMI. An automated stop pump and alarm will be engaged if operating factors such as turbidity or chlorine residuals are detected outside of preset limits.

Metering Station
Metering Stations were installed at both the standpipes in Walkerton. The metering units are designed to provide monitoring capability where a minimal amount of input/output exists and control is not required. These stations particularly identify water levels in the

towers as well as chlorine residuals and will issue alarms if these factors fall outside of the programmed ranges.

Data Concentrator
A Data Concentrator was installed in Port Elgin as part of the Outpost5 ™ System. The Data Concentrator's role in the system is to poll each remote station. The Data Concentrator is subsequently polled by Outpost5 ™ HMI. Additionally, up to 16, 120 VAC discrete and 13, 4-20 mA analog signals can also be monitored locally by the Data Concentrator.

Tower Repeater
A Tower Repeater is installed in Paisley. This unit is similar to the Metering Station in I/O monitoring capabilities, but has been designed to act as a repeating node within a communications network. The only I/O this will monitor will be standpipe levels.

Human Machine Interface
The Outpost5 ™ HMI is installed at OCWA's Southampton Hub office. This interface uses a combination of hierarchical maps and organizational trees to navigate through dozens of facilities quickly and easily. The Outpost5 ™ HMI consists of five main parts:

1. Data Acquisition;
2. Graphical Interface;
3. Alarming;
4. Trending; and
5. Data Storage.

The HMI can be viewed from standard Web browsers on any Windows client (NT, 95 or 98) connected to the OCWA local area network (LAN). In this manner, information about the Walkerton Water Supply and Distribution System is also monitored at the Walkerton PUC office. When an operator selects a specific remote station to view, the HMI dynamically creates the necessary screens. Each station within the Walkerton Water Supply and Distribution System has several information screens such as: View, Alarms, Configure, Communications and Trending.

Trending Screen
The Trending Screen is generated by the Outpost5 ™ HMI. This screen is a powerful analysis tool which makes use of the following features:

- A virtually unlimited number of traces, each containing up to 32,767 data points.
- Up to six y-axes.
- The ability to load, save and delete custom trends.
- Exporting of graphics in the form of bitmaps or JPEG compression formats.
- Exporting of user selectable raw data.
- Multi-axis zooming.

Standpipe #1

Description:

Location: - Southwest Sector of Walkerton
- North of Highway 4 & 9, East of Wallace Street

GPS Reading: - 44° 06' 48" latitude
- 81° 09' 73" longitude

Base Elevation: - 287.49 metres

Diameter: - 8.5 metres

TWL: - 313.71 metres

Liquid Volume: - 1,487.10 m^3

The standpipe is fed directly from the distribution grid from the well pumps online. There are two valve chambers for Standpipe #1, both located on the side of the tank facing Wallace Street. The chamber nearest the standpipe provides access to the drain valve. The main valve chamber provides access to the main feed/draw line to the tower, and to the control and monitoring equipment. Access to each valve chamber is through a steel hatch, which is kept locked when not being checked or worked on.

Key Quality Control Checks:

The following quality control checks are being conducted on Standpipe #1 of the Walkerton Water Supply and Distribution System as part of OCWA's ongoing Operations and Maintenance procedures.

- Check and record chlorine residual reading.
- Calibrate chlorine residual analyzer weekly with a field unit:
  - use sample from the analyzer drain line for comparison purposes; and
  - residual analyzer probe is to be maintained in a liquid at all times when not in use.
- Check and record standpipe pressure and level.
- Check standpipe and chambers for any leakage.
- Check and clean the tank vent area to keep debris from entering.
- Ensure site security prior to leaving premises.

Standpipe #2

Description:

Location: - Northeast Sector of Walkerton
- North of Frank Street, East of Cunningham Road

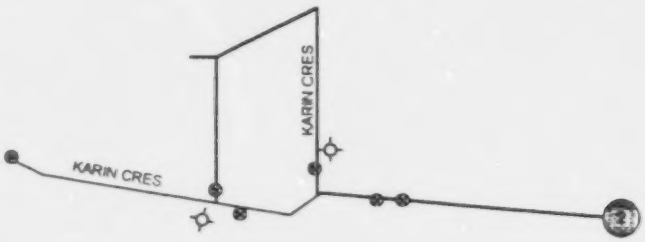
GPS Reading: - 44° 27' 80" latitude
- 81° 20' 57" longitude

Base Elevation: - 294.64 metres

Diameter: - 14.6 metres

TWL: - 314.86 metres

Liquid Volume: - 3,383.42 m^3



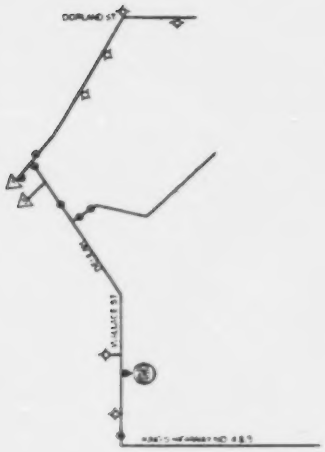
This standpipe is located within a fenced area. It is fed directly from the distribution grid from the well pumps online. There is one valve chamber for Standpipe #2, located on the Southwest side of the tower. The chamber nearest the standpipe provides access to the drain valve. The main valve chamber provides access to the main feed/draw line to the standpipe, the drain valve, and to the control and monitoring equipment. Access to the valve chamber is through a steel hatch which is kept locked when not being checked or worked on.

Key Quality Control Checks:

The following quality control checks are being conducted on Standpipe #2 of the Walkerton Water Supply and Distribution System as part of OCWA's ongoing Operations and Maintenance procedures.

- Check and record chlorine residual reading.
- Calibrate chlorine residual analyzer weekly with a field unit:
  - use sample from the analyzer drain line for comparison purposes; and
  - residual analyzer probe is to be maintained in a liquid at all times when not in use.
- Check and record standpipe pressure and level.
- Check and record standpipe and chambers for any leakage.
- Check and clean the tank vent area to keep debris from entering.
- Ensure site security prior to leaving premises.

Water Well #5



Description:

Location: - Southwest Sector of Walkerton
- North of Highway 4 & 9, East of Wallace Street

GPS Reading: - 44° 06' 89" latitude
- 81° 09' 94" longitude

Static WL: - 284.26 metres

Capacity: - 22.7 litres/second
- 1,963 m^3/day

The water pumped from this well station directly supplies the distribution grid and the standpipes. The pump system is located within a well building.

Key Quality Control Checks:

The following quality control checks would be conducted at Well #5 of the Walkerton Water Supply and Distribution System as part of OCWA's ongoing Operations and Maintenance procedures if the well was brought back into production.

- Check sodium hypochlorite tank:
  - use 12% sodium hypochlorite; and
  - check for tank leaks.
- Check and record sodium hypochlorite flow rate:
  - Set pump stroke and speed to posted settings for required dosage.
- Check Operation Metering Pump:
  - Noise, vibration.
- Check and record sodium hypochlorite tank level:
  - replenish tank if 50 litres or less remaining
- Check and record pump pressure reading:
  - under normal operation the reading should be in the range of 65 – 70 psi (447 – 482 kPa).
- Check and record flow reading:
  - flow rate reading in gallons per minute (normally around 230); and
  - total flow.
- Check and record pressure in main system:
  - under normal operation the pressure is 30 – 40 psi (206 – 275 kPa).
- Check and record chlorine residual reading.
- Calibrate chlorine residual analyzer weekly with a field unit:
  - use sample from the analyzer drain line for comparison purposes; and
  - residual analyzer probe is to be maintained in a liquid at all times when not in use.
- Check and record drawdown on well:

- gauge must read less than 16 feet (4.88 metres).
- Check and record pump/motor operation:
  - vibration, heat and oil level.
- Ensure site security prior to leaving premises.

Water Well #6

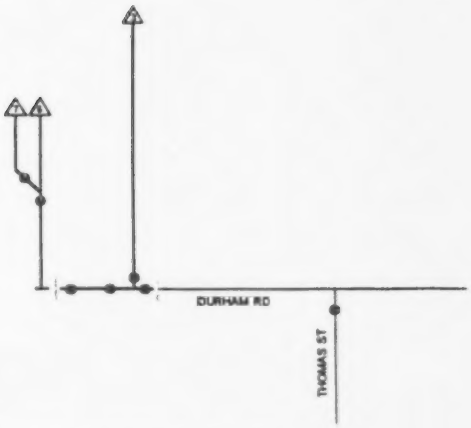
Description:

Location: - Lot 7, Concession 6, NDR, Brant Township
180 metres North of Durham Rd.

GPS Reading: - 44° 07' 55" latitude
- 81° 12' 27" longitude

Base Elevation: - 286.66 metres

Capacity: - 21.3 litres/second
- 1,840 m^3/day



The water pumped from this well station directly supplies the distribution grid and the standpipes. The pump system is located within a well building.

Key Quality Control Checks:

The following quality control checks are being conducted at Well #6 of the Walkerton Water Supply and Distribution System as part of OCWA's ongoing Operations and Maintenance procedures.

- Check gas alarm:
  - green light = OK;
  - amber light = CAUTION;
  - red light = LEAK.
- Check and record Cl_2 flow rate:
  - adjust chlorine gas flow rate based on required residual.
- Check Cl_2 pressure differential:
  - pressure from cylinder must not be higher than water pressure.
- Check and record Cl_2 cylinder contents based on weight:
  - replace cylinder after automatic switchover has occurred; and
  - clearly mark and identify used cylinder and record identification number.
- Check and record chlorine residual reading.
- Calibrate chlorine residual analyzer weekly with a field unit:
  - use sample from the analyzer drain line for comparison purposes; and
  - residual analyzer probe is to be maintained in a liquid at all times when not in use.
- Check and record well pump pressure reading:
  - under normal operation, the reading should be in the range of 60-70 psi (423-482 kPa).
- Check and record flow readings:
  - flow rate reading in gallons per minute (normally around 280); and
  - total flow.
- Check and record pressure in main system:

- under normal operation, the pressure is 45-65 psi (310-448 kPa).

- Check and record drawdown on well:
  - gauge must read less than 70 feet (21.3 metres).
- Check and record pump/motor operation:
  - vibration, heat and oil level.
- Ensure site security prior to leaving premises.

Water Well #7

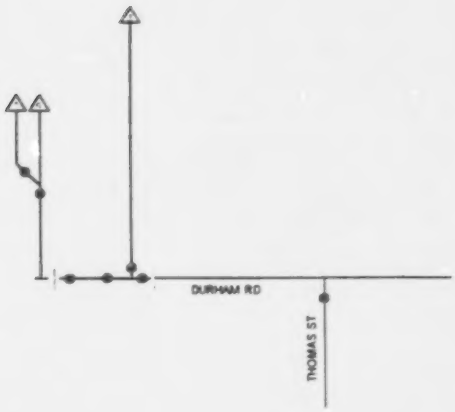
Description:

Location: - Lot 7, Concession 6, NDR, Brant Township;
- 180 metres north of Durham Rd;
- approximately 350 metres west of Well #6

GPS Reading: - 44° 07' 66" latitude
- 81° 12' 48" longitude

Static WL: - Flowing well

Capacity: - 56.8 litres/second
- 4,907 m3/day



The water pumped from this well station directly supplies the distribution grid and the standpipes. The pump system is located within a well building.

Key Quality Control Checks:

The following quality control checks are being conducted at Well #7 of the Walkerton Water Supply and Distribution System as part of OCWA's ongoing Operations and Maintenance procedures.

- Check gas alarm:
  - green light = OK;
  - amber light = CAUTION; and
  - red light = LEAK.
- Check and record Cl_2 flow rate:
  - adjust chlorine gas flow rate based on required residual.
- Check Cl_2 pressure differential:
  - pressure from cylinder must not be higher than water pressure.
- Check and record Cl_2 cylinder contents based on weight:
  - replace cylinder after automatic switchover has occurred; and
  - clearly mark and identify used cylinder and record identification number.
- Check and record chlorine residual reading.
- Calibrate chlorine residual analyzer weekly with a field unit:
  - use sample from the analyzer drain line for comparison purposes; and
  - residual analyzer probe is to be maintained in a liquid at all times when not in use.
- Check and record well pump pressure reading:
  - under normal operation the reading should be in the range of 110 – 120 psi (758 - 827 kPa).
- Check and record flow readings:
  - flow rate reading in gallons per minute (normally 500 – 700); and
  - total flow.

- Check and record pressure in main system:
  - under normal operation the pressure is 45 – 65 psi (310 – 448 kPa).
- Check and record drawdown on well:
  - as applicable.
- Check and record pump/motor operation:
  - vibration, heat and oil level.
- Ensure site security prior to leaving premises.

APPENDIX D

LOCATION OF DEAD ENDS ON WATERMAIN

NOTES

DETAILS OF STANDPIPES

STANDPIPE	DIA. (mm)	ZONE	TOP WL (m.A.S.L.)
1	25	2/49	313.71
2	14.5	294.64	314.86

2 DETAILS OF WELL SUPPLIES

WELL	FLOOR LEV. (m.A.S.L.)	CAPACITY (L/s)
1	296.79	12.5
2	297.58	19.8
3	297.98	13.3
5	294.26	22.7
6	296.66	27.3
7		58.8

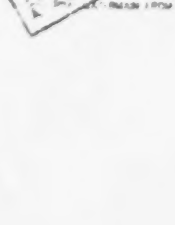
LEGEND

- WATERMAIN & DIAMETER
- WATER VALVE
- HYDRANT
- (2) WATER TOWER & No
- WELL & No

- [illegible]
- [illegible]
- NEW FIRE HYDRANTS
- REMOVAL OF DEAD ENDS
- DEAD END RIGHTS
- LOOPS / REPLACEMENTS

AS AT 31 MAY 1980 THE APPROXIMATE LENGTHS OF EXISTING WATERMAINS AS OF THIS DATE

DURHAM STREET	300mm DIA WATERMAIN FROM [illegible] STREET TO MAIN STREET
COLBORNE STREET	150mm DIA WATERMAIN [illegible] TO NAPIER STREET
NAPIER STREET	150mm DIA WATERMAIN [illegible] TO ROBINSON STREET
ROBINSON STREET	150mm [illegible] STREET TO [illegible]
MAIN STREET	[illegible] JANE STREET TO PRINCE STREET
MAIN STREET	[illegible] DIA WATERMAIN FROM SCOTT STREET TO JANE STREET
HIGHWAY No 9	[illegible] FROM MAPLE STREET TO GROVE DRIVE



B.M.ROSS AND ASSOCIATES LIMITED CONSULTING ENGINEERS GODERICH ONTARIO				TOWN OF WALKERTON P.U.C.	FILE No. 00086
DATE JUNE 30/92	DRWN - T.J.P. CHKD - F.C.V.	SCALE 1:5000		WATERMAINS	DWG No. 1

APPENDIX E

SWABBING SECTIONS

180m

235m

230m

210m+

---- SWABBING TO JUNE 19th

NOTES

DETAILS OF STANDPIPES

1. STANDPIPE	DIA. (m)	ELEVATIONS (m.a.s.l.) BASE	T.W.L.
1	6.3	287.48	313.71
2	14.8	294.64	314.88

2. DETAILS OF WELL SUPPLIES

WELL	FLOOR ELEV. (m.a.s.l.)	CAPACITY (l/s)
1	282.78	33.3
2	283.56	28.8
3	287.58	13.5
5	284.28	22.7
6	288.06	21.3
7		36.8

LEGEND

- WATERMAIN & DIAMETER
- WATER VALVE
- HYDRANT
- (2) WATER TOWER & No.
- (1) WELL & No.

APPENDIX F

DISINFECTION RESPONSE CENTRE AND COMMUNICATIONS ACTIVITIES

Disinfection Response Centre

DESCRIPTION

OCWA established the Disinfection Response Centre in Walkerton for residents to contact regarding questions, issues or concerns with the swabbing and disinfection work.

OBJECTIVES

- To provide immediate responses to residents' requests for information related to the ongoing work of the remediation and disinfection of the Walkerton Water Supply and Distribution System.
- To provide regular communication about upcoming work or any changes in the work schedule.
- To coordinate access issues with the staff working on the disinfection project.

PROCESS

At an early stage of the remediation planning process, it became apparent that in order to carry out the necessary work as efficiently and effectively as possible, a framework was needed for facilitating quick, complete and up-to-date communication of information to the residents of Walkerton as work progressed and as specific issues arose.

In order to meet this communication need, OCWA established a Disinfection Response Centre, which citizens could contact 24 hours per day in order to obtain specific information regarding the progress of work, or to answer specific questions regarding work on their street(s) or at their home(s). Through the Disinfection Response Centre, members of the public were able to get immediate answers and often a personal follow-up visit in response to specific issues of concern.

As part of its duties, the Disinfection Response Centre coordinated the work of local volunteers from the Royal Canadian Legion. These volunteers distributed the daily notices to residents regarding impending work in their neighbourhoods as well as the emergency notification of residents when last minute schedule changes were necessary.

The Disinfection Response Centre also served as a repository where residents could leave house keys or other pertinent information related to building access for the building-to-building disinfection program.

The Disinfection Response Centre served as the strategic centre for the swabbing, the building-to-building disinfection, all plumbing repairs due to the superchlorination, and the sampling programs.

PROTOCOL

DISINFECTION RESPONSE CENTRE RESPONSIBILITIES

Location and Hours of Operations

The Disinfection Response Centre (DRC) was located in the basement of the PUC building at 4 Park Street, Walkerton, Ontario. During the swabbing and building-to-building disinfection processes, the centre was open and operating with a full staff (five to eight staff members) from 6:00 am to 10:00 pm. However, the centre was also open for extended hours to correspond with the disinfection crew schedules. Telephone calls received after office hours were forwarded to a cellular phone in the possession of Disinfection Response Centre staff. This was done in order to provide 24-hour response service.

The following is a summary of the responsibilities of OCWA employees at the Disinfection Response Centre in Walkerton.

1. Inbound Telephone Communications

One of the primary duties of the staff members of the Disinfection Response Centre was to respond to or redirect incoming telephone calls from local residents with respect to issues surrounding the ongoing disinfection process. Three (rollover) telephone lines were designated for this purpose at the Disinfection Response Centre, with the main telephone number being (519) 881-3272.

Because of the inconveniences and stresses that many of the Town's residents were subject to because of the water contamination and the subsequent cleanup effort, great emphasis was placed on OCWA employees handling all incoming telephone inquiries and requests in a polite and friendly manner.

During the swabbing and disinfection process, the Disinfection Response Centre received an average of 200 calls per day. Most calls were received once the notices had been delivered. In general, questions were simple and could usually be addressed to the caller's satisfaction within one or two minutes. When crews encountered problems which caused work delays and/or water service disruptions, the call volume typically increased.

In the event of a concern or issue that could not be resolved over the telephone, personnel from the Disinfection Response Centre would conduct a site visit in person. Reasons for these site visits included explaining the status of particular operations underway, evaluating and promoting cistern disconnection or responding to a plumbing issue related to the swabbing and/or disinfection processes.

1. a) Walkerton Homes Database Entry

Operating protocol for the Disinfection Response Centre required all incoming calls to be logged in the Walkerton Database. Response Centre employees were

instructed to obtain as much information from callers as possible (e.g., first and last name, address, telephone number). The database included an "Issues" section where comments and questions were inserted. An "Action" section was also incorporated into the database, where OCWA employees input their response to the call. Each entry was dated. In addition, a "Response" section of the database allowed OCWA to track progress in resolving calls as they were filed. If a call was effectively resolved or if no follow up was required, the "Yes" section in the "Response" category was checked off. All employees were informed of the critical need to keep this database up to date and complete.

1. b) Telephone Inquiry Response Procedures

To ensure the consistency and accuracy of the information being provided by OCWA employees at the Disinfection Response Centre, standard responses were generated for the most common subject headings and topics. ***The following is a summary of those subject headings and the responses that were recommended:***

- **Issues around swabbing**

  During the swabbing process, a section of the town will be without water service – usually from 8:00 a.m. to 5:00 p.m. Neighbouring areas may be affected and can experience low to no water pressure during this time. Apologize to the caller for the inconvenience and explain that their service should be restored by the end of the day. Advise them to call back if they continue to experience service disruptions. If they do continue to experience problems, contact Marc Campbell at A1 Hydrants.

- **Issues around disinfection**

  During the disinfection process, a section of town will be without water service for 24-36 hours. On the first day, a team will go into the resident's home, confirm the presence of high-strength chlorine at each fixture and tag all water outlets. On the second day, the team will return to dechlorinate and then remove the red tags. Once the tags are removed, water can be used – as per the Boil Water Order.

  During water shut-offs, residents can use their toilets. However, they must dump water directly into the bowl to activate flushing. Advise residents to fill buckets of water prior to the water shut off. Portable toilets and showers are available for use at a designated area in the town.

- **Cisterns and wells**

  Reed & Schaab, a local plumbing company, has access to the Walkerton Database. The company is sorting through the database and identifying all customers with cisterns, wells and boilers without backflow preventers. They will set up appointments with residents and will update the database when service calls are completed. The resident has the choice of keeping their cistern or converting to town water. If they choose to keep their cistern, all

cross connections with the town water supply will be severed. If they choose to convert to the town water supply, the pump system will be removed and retained as evidence for the inquiry – they will not be returned to the resident. A water softener will be installed, free of charge to the resident, if they choose to convert to town water.

- **Ice makers and humidifiers**

  Ice Makers: A red tag will be left on all refrigerators with an ice maker unit. Advise the resident not to use the unit until the red tag has been removed by a certified plumber authorized by OCWA. The resident is required to make ice cubes on a daily basis. The ice cubes must be discarded. This will allow the chlorinated water to disperse through the water pipes in the refrigerator. Advise the resident to continue making ice and discarding the cubes until the Boil Water Order has been lifted by the Medical Officer of Health. If the unit has a filter, the filter must be discarded and replaced.

  Humidifiers: Advise the resident to remove the filter pad. Take out the tray and wash thoroughly in bleach. The float must be cleaned out and washed in bleach. The filter must be removed and replaced with a new one.

- **Water Softeners and Coolers**

  Culligan is responsible for the disinfection of all water softeners. A representative from Culligan reviews the Giffels reports to identify homes with water softeners. Appointments are made directly from Culligan with the resident. Please note that water coolers are not being purchased by OCWA for residents.

- **Plumbing**

  If a plumber is required for service, a call is made to Sternall's or Reed & Schaab. Indicate in the "Issues" section of the Walkerton Database what the problem is and in the "Action" section, indicate which plumber was called. Both companies will call back with an update on the service call. Enter in the action section that the job was completed and indicate what was done (e.g., 2 pipes repaired, one pipe replaced, etc.). (Both companies will indicate the address the service was completed at). If Howard's Plumbing is used, make sure an estimate is prepared prior to approving work to be done. Howard will bring invoices to the centre. (Bob will check the invoices against the estimates.) Using the invoices, find the address in the database where the work was completed. In the "Action" section, indicate that Howard's Plumbing & Electric completed the plumbing and indicate the invoice number and date.

- **Sampling Details (starting & completion dates to be confirmed)**

  There are two teams working in the city:

- **Audit Team**: This team has been sampling 1 in 3 houses. They began June 12, 2000 and are almost done. The team will then be recruited to help out the other team if positive results come back. The audit team has been following the disinfection route.

- **System-Wide Sampling Team**: This team is sampling at every single home. Sometimes this crew is called the "validation crew", request clarification when speaking with the team. This needs to happen two weeks after disinfection.

  You may get calls from people saying that they have already been tested. They may have been tested a few weeks ago by the audit team. The System-Wide Sampling, as explained above, will test every home – so several homes will be tested twice. Apologize for the confusion and inconvenience, and explain that there are two teams performing two different sets of tests. Contact Brent Zehr for details and purpose of each team.

- **Media**

  OCWA is typically commenting on the progress made to date, resources that are deployed in Town to clean up the system, etc. (in other words, the Agency is commenting only on what is known). Television crews have been interested in filming the disinfection process, but were only able to videotape in a home if the resident consented. With regard to any media contact, it is not OCWA's role to speculate about the potential source(s) of the contamination.

- **Request for Water**

  Residents (elderly people or shut-ins) sometimes make requests for OCWA to deliver bottled/bulk water to them. If there is sufficient staff coverage at the Disinfection Response Centre, a delivery can be made. Bottled/bulk water is available at the Community Centre located off Durham Street. Make sure you have the Response Team Identification Badge visible when you visit the home.

- **Night Duty / On Call**

  After hours, the Disinfection Response Centre phone number is forwarded to the Centre's cell phone. One person is designated as the Night Duty officer or On Call officer. All the calls must be recorded in the Night Duty / On Call log book. The next morning, the calls must be entered into the database.

- **Activity Notification (a copy of all notifications to follow – and paper colour)**

  A volunteer group of local residents delivers the notices to affected homeowners advising them that we are going to be doing work in their neighbourhood the following day. The group meets at the Brockton Municipal

Office at 4:00 p.m. The briefing is led by OCWA staff (usually Bob Simpson) and maps indicating affected homes are provided. Lisa Volpini has been hired by the town to act as the Public Relations contact. She will draft the notices that the volunteers will deliver. These will be printed on goldenrod paper.

- **Access Issues**

HOW TO ADDRESS "ACCESS" RELATED CALLS:

- ***Leaving the door open:*** If the homeowner is leaving the door open, advise them to leave a note on the door with the following: "CALL CENTRE FOR ACCESS". Log in database the address and name indicating the door will be left open. Amy Campbell and crew will radio the centre for access. Advise her that the door is open and that they have permission to enter.

- ***Leaving keys with someone else:*** If the homeowner is leaving their keys with a neighbour or someone else, please obtain as much information as possible, i.e., the name of the person who will be holding the keys, their phone number and alternative number if available, and address. Advise the homeowner to leave a note on the door with the person's phone number, e.g., "PLEASE CALL _____ AT _____ FOR ACCESS". Log all info in the database.

- ***Keys left at the centre or dropped off at the PUC:*** If keys are dropped off at the centre or PUC front desk, you MUST enter the name and address for the key in the database – we need a record of all keys kept at the centre. Indicate in the "*ISSUES*" section that the key is in the locked box at the centre.

- ***Call for Access:*** If someone wishes to be called from work (or wherever) to open up their house, tell them to put a note on their front door with the following: "PLEASE CALL _____ AT ____ FOR ACCESS". Make sure all alternative numbers are logged on the database.

HOW TO ADDRESS ACCESS ISSUES:

- Once the volunteers have returned the access / notification sheets, go through them and enter all addresses (and related information) that have access issues.

- From the house-to-house map, make a list of all the houses by street name and number that are scheduled for disinfection.

- Use the list to go through the database. Open each entry in the section scheduled for disinfection to identify access issues – do not rely on the "access" sort field. We have noticed that the "Access Issue" check box has not always been checked when it concerns access.

- Print out all Access Issue entries.

- Go through the printouts and make appropriate calls, e.g., if someone has left keys with a neighbour, contact that person to confirm they will be available. The more we can confirm prior to disinfection day the easier it will be for the crews.

- Sort the printouts (entries) by street names in ascending numerical order - paper clip all the entries by street together.

- Place all printouts in a large brown envelope indicating on front: *Access Issues for _____ (date)*.

- All the keys that the centre has in the locked box that are needed for that section are to be placed in the envelope. Indicate on the front: *KEYS FOR _____* (indicate the addresses).

- The morning of disinfection, contact Amy Campbell by radio (usually around 8:15 a.m.) to determine her location. Have someone bring the envelope to her.

- The day following dechlorination, Amy Campbell will return any keys she has been given.

HOW TO FIND NAMES & NUMBERS FOR ADDRESSES:

The PUC has a database that allows a user to search for a name and number from an address (reverse directory). This is a very useful tool when addressing access issues, particularly when using the information from the volunteers. Valerie or Janice from the PUC can help you with the computer (if there are several), or will search an address for you.

HOW TO ADDRESS "NO ACCESS" ISSUES:

If the situation arises that the crews can not gain access into a building, a call must be made to the MOE. Someone will meet the crews at the building in question, along with a locksmith and a police officer. Please note that this is a ***last resort.*** Sometimes detective skills are required to avoid this situation. For example, using the information found on the PUC's reverse directory, we were able to locate a tenant for an apartment that we did not have access to. Using 411 we found a new listing for them. Once contacted, they provided us with the name of the landlord and where he worked. Try calling a neighbour if no one is home. It's a small town, and everyone knows everyone – they may have useful information.

*** PLEASE INPUT ALL INFORMATION IN THE DATABASE. TAKE THE TIME TO MAKE SURE ALL INFORMATION IS CORRECT AND THAT ALL SECTIONS ARE FILLED IN COMPLETELY. THE MORE UP TO DATE AND ACCURATE THE DATABASE IS, THE EASIER OUR JOB IS (AND THE CREW'S). ALSO, BE CONSISTENT.
Thank you!

- **Daily Report**

A daily report is prepared and submitted via e-mail to OCWA head office by 9:00 a.m. the following day. It is a record of all the events that have taken place throughout the day. An update from Compliance, Operations, A1 Hydrants, OSO, Small Water System Operations, the Centre, Contamination Investigation, Rick Turnbull, etc. must all be included in the report. A copy of the report is filed in the "OCWA Daily Report" binder.

- **Cable Report**

Every day at 2:00 p.m., an OCWA representative (typically Client Services Representative Peter Harrison or Marketing Manager Wilf Argue) does a 10-minute update on the local cable station. This individual reports on the next day's planned events (i.e., swabbing, disinfection, sampling) and provides updates on any other relevant issues. Either Mr. Harrison, Mr. Argue, or another designated Disinfection Response Centre staff member prepares the report each day. For this purpose, an update is required from A1 Hydrant Services and/or the Ministry of the Environment regarding upcoming events.

- **Daily Checklist**

DAILY CHECKLIST

Date: _____

- CHANGED BACKUP TAPE
- SENT OUT DAILY UPDATE
- ADDRESSED ACCESS ISSUES
- UPDATED HOUSE-TO-HOUSE SAMPLING MAPS
- CHECKED RADIOS (ALL TURNED OFF AND CHARGING)
- ALL CALLS HAVE BEEN LOGGED AND ISSUES ADDRESSED
- WALKERTON E-MAIL ACCOUNT CHECKED

- **Miscellaneous**

- ***Giffels & Plumber's Inspection Report***

Olie or Dennis from Giffels will bring their reports along with the Plumber's Inspection Reports to the Disinfection Response Centre. A copy of the Giffels' report is to be given to Darryl from Culligan. The original copies along with the Plumber's Inspection Report are to be given to Anne Cruickshank. Anne will enter both reports into the database and will file both in the "Giffels & Plumber's Report" binder. The reports are filed by street name. (That is

why it is important to give Darryl a copy prior to filing – he needs the reports by date.)

- ***Red Tags***

  Red tags are left on water softeners, ice makers, humidifiers, etc.. When the plumbers go through after disinfection, these tags are returned to the Centre. ***Give all tags to Pierre Solda.***

RESULTS/CONCLUSION

- The Disinfection Response Centre opened on June 12, 2000 and will operate until October 16, 2000.
- The Centre responded to an estimated 12,850 telephone calls and carried out personal visits to a significant number of residences in Walkerton in order to deal with specific issues.
- The Disinfection Response Centre database contains over 17,000 entries associated with the remediation effort.
- The Disinfection Response Centre has coordinated the delivery of information notices for both the swabbing and the disinfection procedures for every residence, institutional and commercial building in Walkerton, as well as providing special notices related to other system disruptions. This effort has included the coordination of approximately 2,000 work hours of volunteer support.
- The work of the Disinfection Response Centre has made significant progress in fostering a cooperative relationship between the citizens of Walkerton and the many workers involved in the remediation of the Walkerton Water Supply and Distribution System.
- Given the urgent time constraints inherent in this process in Walkerton, the positive relationship between the residents and the work crews has helped to enhance the ability of OCWA and its contractors to work through this complicated remediation effort in a timely and effective manner.

Communications

DESCRIPTION

This section outlines the general communications activities associated with the overall remediation effort in Walkerton, including those activities aimed at keeping the general public and the media informed of ongoing work, progress and developments on a continual basis.

OBJECTIVES

- Communicate timely and accurate information about ongoing remediation efforts to the residents of Walkerton through regular updates (e.g., municipal newsletters) and through the local news media (e.g., interviews, public service announcements).

- Keep Walkerton residents apprised of the progress of the disinfection of the local water supply system (e.g., timing and locations of water service disruptions).

- Respond to media interview requests in a timely manner and provide accurate information regarding the progress of the remediation effort.

- Maintain regular communications with the various agencies collaborating on all aspects of the overall water system remediation.

PROCESS

In late May 2000, the events surrounding the water contamination in Walkerton catapulted the small town onto the national and international news scene. Along with this intense media attention came a need to field and manage media requests (e.g., requests for interviews) in a timely and effective manner.

While the Municipality of Brockton handled many of the media requests, particularly in the earliest stages of the crisis, OCWA began to play a more prominent media relations role once the operational component of the remediation plan began. Communicating details about the progress of the operational plan to the media required a consistent and systematic approach in order to ensure that the needs of the reporters were met.

Over the course of the remediation program, OCWA media representatives conducted a number of interviews with numerous media outlets, including local, national and international print and broadcast journalists.

On the local level, there was also a pressing need to keep residents informed of the progress and schedules of the various operational initiatives (e.g., swabbing, building-to-building disinfection, sampling, etc.) because of the impact that some of these activities had on residents (e.g., water service disruptions, issues around access to buildings, etc.).

One of the most effective informational tools developed by OCWA to help provide Walkerton residents with timely and accurate information about these initiatives was the daily cable television update. Each day, an OCWA representative presented a 10-minute operational update, which was videotaped at the local cable television station. These updates were broadcast as many as five times per day on the local cable channel, giving residents numerous opportunities each day to become current with the latest operational developments.

These daily cable television updates were used to convey a wide range of information to the residents of the community, including locations of the flushing, swabbing and disinfection programs, public service announcements (e.g., the availability of special services such as the bulk/bottled water supply, upcoming public information sessions, etc.). The main purpose of the cable television updates, however, was to inform residents about the progress on swabbing and disinfection activities to date and to report on the next day's planned swabbing and disinfection activities.

In addition to the daily cable television updates, public service announcements also appeared in area newspapers and on local radio stations. OCWA also provided information updates for the municipality's community newsletter that dealt specifically with the Walkerton remediation effort (the Brockton Buzz).

PROTOCOL

Media Relations

- Media inquiries were directed to designated OCWA spokespersons.
- Any contacts with news reporters were logged and recorded by OCWA staff.
- A comprehensive media monitoring function, operated out of OCWA's Toronto office, tracked relevant news articles.

Daily Cable Television Updates

- Realizing the importance of communicating daily progress and scheduling updates to as many residents as possible, across as many different media as possible, OCWA arranged to have daily updates videotaped and broadcast on the local cable television provider, Saugeen Telecable (located on 7th Avenue in Hanover, Ontario).
- Each day at approximately 2:00 p.m., a representative from OCWA (usually Peter Harrison or Wilf Argue) arrived at Saugeen Telecable for the videotaping session. A station employee videotaped the daily update, which was usually approximately 10 minutes in length.
- Once the update had been videotaped and edited (when required), it was broadcast several times per day in order to reach the widest possible audience within the community. Daily cable television updates for a typical day were aired at 4:00 p.m., 6:00 p.m., 8:00 p.m., and 10:00 p.m. as well as at 8:00 a.m. and 12 noon the following day.
- The daily cable television updates were broadcast from June 14 (the beginning of the swabbing program) until August 3 (with the completion of the building-to-building disinfection program).

General Information Requests

- General information requests were typically handled by OCWA's Disinfection Response Centre.

Additional Communications Activities

- As part of their overall involvement in the Walkerton remediation effort, OCWA representatives participated in a variety of additional communications activities. These activities included, but were not limited to: liaising with other agencies and organizations working on the remediation effort, press conferences, and making technical presentations at public information meetings (held frequently in Victoria Jubilee Hall in Walkerton).

- OCWA also assisted the Municipality of Brockton with the delivery of automated telephone updates to the residents of Walkerton using a system called Ventriloquist, which sent a pre-recorded message to every telephone subscriber in the Walkerton area. These messages typically addressed locations of swabbing and/or disinfection crews, impending water service disruptions, etc.

RESULTS/CONCLUSION

- OCWA produced daily cable television updates between June 14 and August 3.

- OCWA media relations contacts conducted a number of media interviews between late May and mid-September 2000.

- Residents and business owners in Walkerton were kept informed of the progress of the daily flushing, swabbing and disinfection activities, as well as any other operational issues that developed.

- Timely and effective communications contributed to excellent relationships between the OCWA, the parties collaborating on the remediation and the residents and business owners of Walkerton.

- During the time when crews were entering and disinfecting approximately 1,800 separate residences and businesses, OCWA's focus on open and timely communications resulted in a very low number of complaints from citizens regarding inconveniences or disruptions.

APPENDIX G

WALKERTON FUTURE WATER SUPPLY STUDY – INTERIM REPORT – SHORT TERM SUPPLY

WALKERTON PUBLIC UTILITIES COMMISSION

Walkerton Future Water Supply Study

Interim Report – Short Term Supply

September 2000

R.V. Anderson Associates Limited
consulting engineers, architects, technology managers

RVA #5446

R.V. Anderson Associates Limited

consulting engineers, architects, technology managers

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September 28, 2000 RVA 5446.10

Ontario Clean Water Agency
1 Yonge Street, Suite 1700
Toronto, ON M5E 1E5

Attention: Mr. Andy Valickis, P.Eng.

Dear Sir:

Re: Walkerton Future Water Supply Study
Interim Report – Short Term Supply

We are pleased to submit this Interim Report in support of the current efforts to lift the existing boil water advisory.

We understand this report will be used by the Ontario Clean Water Agency (OCWA), by the Municipality of Brockton, and by the Ministry of the Environment, as support materials for subsequent reports by the above entities.

The report has three recommendations, intended to be implemented in succession. We are currently working on the design and construction supervision for Recommendation No. 1 – Installation of an Interim Filtration System. In the near future, we would like to discuss setting up an action plan for implementing Recommendation No. 2 – Well Upgrades, and Recommendation No. 3 – UV Pilot Testing. One key element of the latter would be to address funding issues.

We remain available to answer questions and provide additional support as may be needed. In the meantime, we will continue with the longer term aspects of this water supply study.

Yours very truly,

R. V. ANDERSON ASSOCIATES LIMITED

LICENSED PROFESSIONAL ENGINEER
K. W. CAMPBELL
Sept 28/00
PROVINCE OF ONTARIO

Ken W. Campbell, P.Eng.
Project Manager

REGISTERED PROFESSIONAL ENGINEER
H. GUTTMAN
00/09/28
PROVINCE OF ONTARIO

Hershel Guttman, P.Eng.
Project Director

HG/kis

WALKERTON FUTURE WATER SUPPLY STUDY

INTERIM REPORT – SHORT TERM SUPPLY

INTRODUCTION:

R.V. Anderson Associates Limited (RVA) was retained by the Ontario Clean Water Agency (OCWA) to identify feasible alternatives and to recommend solutions for the long term and short term water supply needs for the Walkerton Public Utilities Commission water supply system.

The former Town of Walkerton (approximate population 5000) is now a part of the larger Municipality of Brockton. The Walkerton water supply system is administered by the Walkerton Public Utilities Commission (PUC).

Until recently, the Walkerton water supply system consisted of three active wells (No. 5, No. 6., and No. 7), two standpipes, and a series of distribution mains throughout town.

In May of 2000, Walkerton experienced a serious epidemic of bacterial related illness and deaths that have been reported to be linked to the public water supply system. The Medical Officer of Health placed a boil water advisory (BWA) on the system. The Ontario Ministry of the Environment (MOE) subsequently issued a series of Field Orders to the Municipality of Brockton and/or the PUC to deal with the epidemic.

Since that time, we understand the following has occurred:

- OCWA was retained to operate the water system;
- the water distribution system and standpipes were flushed, swabbed, and disinfected;
- portions of the water distribution system were replaced;
- an investigation currently underway has recorded total coliform and E. coli readings at some or all of the active wells during and since May. Some of this data may be related to a major rainfall event that occurred in May, 2000;
- additional backflow protection was included at Well No. 7 to prevent backflow into the well under high water conditions in the adjacent wetland;
- a interim hydrogeological assessment (prepared by Golder Associates, dated August 18, 2000) identified a connection between Well No. 5 and nearby surface water that was likely contaminated by manure. Well No. 5 has subsequently been permanently removed from production;
- the investigations also identified a series of water quality concerns related to Well No. 6, that has led to its removal from operation, leaving Well No. 7 as the only supply to the town at this time; and
- a study related to biofilms in the distribution system was initiated and is currently underway.

In addition, verbal communications with members of this study's Technical Steering Committee (TSC) have indicated that Well No. 7 may be experiencing turbidity episodes up to and possibly in excess of 5 NTU, however it has also been reported that these episodes appear to be linked to the starting of the pump and the occurrence of air in the discharge line.

PURPOSE OF THIS INTERIM REPORT:

The purpose of this interim report is to provide information and recommendations on a short term drinking water supply solution that is capable of meeting the Ontario Drinking Water Standards (ODWS) on an on-going basis and to consider the firm capacity requirements of the Walkerton water system. The report will be used to identify a program that will lead to the lifting of the BWA, and as such, time to effect solutions was a prime factor in most considerations.

In general, the approach taken was based on best industry practices and on the principal of continuous improvements, as follows:

a) develop a source of raw water that provides a firm capacity to meet the quantity demands of Walkerton;
b) optimize the quality of the raw water ;
c) provide the level of treatment necessary to ensure that water delivered to the distribution system is safe; and
d) continue with on-going distribution system upgrades, flushing, and other activities so that contamination of the water within the distribution system does not occur.

QUANTITY OF WATER REQUIRED:

The first issue that was examined was the quantity of water necessary to meet the current water demands in Walkerton. Daily water supply records from 1997 to April of 2000 were reviewed. It was found that the average day demand (Q_a) was 2555 m^3/d.

Maximum Day Demands (Qm) were identified as follows:

Year	Qm (m^3/d)
1997	4539 (July)
1998	4146 (January)
1999	4777(September)
2000	5076 (April)

At a meeting of the project TSC (including representatives of OCWA, MOE, PUC, and the Municipality), it was agreed that a short term firm capacity of at least 4900 m^3/d should be provided ("firm" capacity is the capacity of the system with the largest well/pump out of service).

RAW WATER SUPPLY ALTERNATIVES CONSIDERED:

Once the quantity of water necessary for supply was established, potential sources of "raw water" (i.e. water prior to necessary treatment) was examined. A long list of raw water supply alternatives was developed, and a preliminary evaluation of the alternatives was undertaken. The primary concern for the short term was the speed at which the various alternatives could be brought on line. The following table lists the alternatives and the results of the preliminary investigation:

Possible Sources of Raw Water

Source	Comments	Timing
Well No. 7 alone	inadequate – no firm capacity	existing
Rehab. Well 6 & 7 Well Field plus new well (7a)		6-8 weeks
Upgrade Well 3	quality and location concerns	months
Implement Well 8	quality concerns, EA required, unknown quantity	months
New well(s) in new well field	lengthy investigation period req'd?, EA required	more than 6 months
New river supply	lengthy investigation period, full treatment required, EA required	1-2 years
Pipeline from Douglas Point	lengthy investigation period, partners needed, EA required	1-2 years
Pipeline From Hanover	lengthy investigation period, partners needed, EA required	1-2 years
Other area schemes	lengthy investigation period, partners needed, EA required	2-5 years

It was concluded from this evaluation that the fastest feasible raw water supply alternative to meet the water supply quantity requirement was to upgrade the existing Well 6 and/or Well 7 well field. The following illustrates the point that Well No. 7 alone as a source is inadequate.

To that end Golder Associates Limited and Lotowater Limited (sub-consultants to RVA on this study) were requested to develop a detailed proposal for performing the upgrade. A representative of Lotowater Limited met with the MOE's Regional Hydrogeology staff to discuss the proposed program. A draft proposal is contained in Appendix A. The proposal contains the following general components:

- Consider deepening Observation Well #1 (near Well #6) with the view toward developing it as the back-up well for Well #7.
- If this is not feasible, then consider using it as a back-up shallower well, if water quality concerns can be addressed.
- If none of these are feasible, then modify it as an observation well, while securing it from interconnections between acquifers.
- As a next step, consider developing Well #6, if water quality concerns can be satisfactorily addressed. If not, convert it into a secure observation well (as for Observation Well #1 above). In any case, abandon the adjacent test well by converting it into a secure observation well.
- If back-up capacity is still required, then try developing a new well (7a) about 100 m south of Well #7, as a mechanical back-up to Well #7.

- Seal off the existing Well No. 7 overflow and secure the adjacent test well as an observation well;

- Install a liner in Well No. 7 to seal a small area of significant corrosion and possible leakage in the well casing. Install a new well pump, if necessary, and return the well to service; and

- Continue to monitor raw water quality from any wells being pumped.

LEVEL OF TREATMENT REQUIRED:

Assuming that the Well 6/Well 7 well field will be the short term source of raw water supply for Walkerton as discussed above, the next question that was addressed was the level of treatment required for this raw water source to ensure a safe supply that meets the ODWS.

The MOE's "Procedure B13-3 Chlorination of Potable Water Supplies in Ontario" along with US Federal Regulations were used for this evaluation. Three possible treatment scenarios were identified, as follows:

1. Groundwater: Section 2.1.a. of the MOE procedure states that groundwater requires chlorination only, along with a 15 minute effective contact time. This level of treatment implies a groundwater source that is completely protected from any surface water impacts (i.e. completely secure).

2. Groundwater Under the Direct Influence of Surface Water: The MOE procedure does not carry a definition of this type of raw water. However, the US regulation (Part 141 of the "National Primary Drinking Water Regulations, 40 CFR) contains the following definition of Groundwater Under the Direct Influence of Surface Water:

   > "...means any water beneath the surface of the ground with significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia* or (for subpart H systems serving at least 10,000 people only) *Cryptosporidium*, or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. "

   The definition goes on to state that direct influence must be determined for individual sources in accordance with criteria established by the State.

   In the case of Ontario, we understand that no specific criteria have been established but that the issue will be dealt with on a case by case basis. Any such evaluation would be based on "competent, professional hydrological guidance."

   From the US Regulations, and from discussions with the MOE Assessment and Approvals Branch, we understand that water meeting this definition of "groundwater under the direct influence of surface water" requires full treatment (including filtration) as if it was a surface water. If so, then Section 2.2.a. of the MOE procedure would apply, as follows:

"Achieve, through a combination of filtration and continuous disinfection, a minimum 3-log removal/inactivation of giardia cysts and a 4-log removal/inactivation of viruses at all times at or before the first consumers' connection in accordance with Section 3 of this document." [referring to detailed CT and Log removal requirements]..."Higher removal/inactivation credits may be required for source waters where increased levels of raw water contamination may occur."

These requirements could be met through conventional filtration, direct filtration, slow sand filtration, or membrane filtration, in conjunction with chlorine disinfection. Additional forms of disinfection such as ozone, UV, chlorine dioxide, or chloramination could also be added to the overall treatment process.

3. Groundwater Under the Direct Influence of Surface Water But Not Requiring Filtration: Section 2.1.b of the MOE procedures states:

"Where a groundwater source is determined to be under the direct influence of surface water; and where the source water quality conditions are suitable to avoid filtration as determined by the Ministry; and where there is adequate watershed control to avoid filtration as determined by the Ministry; the system treatment requirements of greater than 3 log reduction of giardia lamblia cysts and greater than 4 log reduction of viruses may be achieved by disinfection only, in accordance with Section 3 of this document."

In this case, the MOE can allow treatment to consist of disinfection only. In the case of raw water from the Well 6 and/or Well 7 well field, the required level of treatment could be provided through a lengthy chlorine contact time (in the order of 3-5 hours), or alternative disinfection in the form of ultraviolet light (UV), ozone, chloramines, chlorine dioxide, or some combination of the above.

To determine which of the three possible treatment scenarios applies to the Walkerton Well 6 and Well 7 in their current condition, we utilized several sources of information:

- Golder's Interim Hydrogeological Assessment, dated August 18, 2000. In this report it is noted Well No. 7 appears to be a secure groundwater supply, but on the condition that the test well TW1-86 is properly grouted and the small area of significant corrosion in the casing of Well No. 7 is further investigated (and repaired if necessary);

- A verbal communication from the TSC that the final Golder Report states that there is a hydrogeological interconnection between Well 6 and Well 7.

- A summary of weekly bacteriological test results from January of 1999 to May of 2000 (including a Well 7 May 15 reading of total coliforms and E.Coli in excess of 200), along with daily bacteriological test results from May 30, 2000 to September 10, 2000 provided by B.M. Ross and Associates Limited (See Appendix 'C'). This data shows that total coliforms occur in the raw and/or treated water samples on 29% of the days for Well 6, and 15% of the days for Well 7. It is generally considered that such an occurrence is indicative of surface water contamination; and

- Daily turbidity readings for Well No 6 and Well No 7 between August 23, 2000 and September 9, 2000, provided by the Ministry of the Environment, summarized in a table in Appendix 'C'. This data shows low turbidity in both wells (<0.01 NTU) on many days, but with turbidities rising to as high as 12 NTU in Well 6 and 0.6 NTU in Well 7. The most significant feature of this data, however, is that the turbidity was observed to rise from the background levels in both wells during the same time period. While this has not been compared against rainfall data, the fact that turbidities rise together, could be an indication that both wells are subject to surface water influences, and is suggestive of an interconnection from Well 6 to Well 7.

On this basis, it is not possible to state conclusively at this time that these wells are secure. Persistent low levels (and occasional high levels) of total coliform results recorded through the summer of 2000, turbidity that varies in Well No. 6 and Well No. 7 simultaneously, as well as the reported contamination event that occurred in May of 2000 each give rise to this uncertainty. We would therefore conclude that the "Groundwater" designation and disinfection-only approaches would not be appropriate for the current well installations at this time.

It is our opinion that in the long run, after the well field upgrades, the technology of choice for this situation would likely be UV and chlorine disinfection. However, at this time, UV as a primary disinfectant on ground water is still in the developmental stage, and there are too many unknowns about the water quality in Well No. 6 and Well No. 7 to know the long-term effectiveness of UV. Given time, further investigations and the completion of the well upgrades, these unknowns can likely be resolved.

In the short term, however, the priority is the lifting of the BWA. We therefore recommend that filtration be provided as an interim measure, until such time as a long term solution (possibly utilizing UV) can be applied.

FILTRATION ALTERNATIVES CONSIDERED

Based on the short term conclusion that filtration should be used, we investigated a wide range of possible filtration alternatives (this investigation is described in Appendix B).

The limited rapid response from potential suppliers provided two alternatives, namely pressure conventional filtration, and membrane filtration. In comparing the two in Appendix 'B', the pressure filtration presented the following three problems:

- it required treatability testing to assess chemical and residue management needs.
- equipment delivery would be 3 to 6 weeks.
- in any case, residue management facilities would be needed.
- there was no rental option for this unit.

Residue management facilities would likely have involved some form of settling and thickening and the need to truck considerable volumes of solids to the pollution control plant in town. It should be noted that there is a lack of a well defined receiving stream nearby, and solids from the chemicals to be added would have no beneficial effects for the area.

These problems can be compared with the results of the findings for the Zenon membrane filtration unit, namely:

- No treatability test required, as chemical addition is not needed.
- Equipment delivery of 2 weeks (the unit already exists).
- Without the addition of chemicals, there would be only minor residue management issues to address.
- The nearby wetlands would likely benefit from the clean waste stream from the unit.
- Chemical cleaning requirements would necessitate only infrequent trucking of low volumes of waste to the pollution control plant in town.

Based on the above considerations, and given the limited time available for allowing the BWA to be lifted, membrane filtration was selected as the treatment of choice in this case.

There were two choices available for membrane filtration. The first, supplied by Degremont/Aquasource was compared to the second unit available and supplied by Zenon.

Both units were found to be built and available, but the Degremont unit was in Texas, and it lacked a membrane cleaning unit. The Zenon equipment on the other hand was self-contained, fully equipped, and available in Ontario.

Although delivery and costs were comparable, the Zenon system was selected as superior for this particular installation and under the particular time pressures of this project. The reasons were as follows:

- Uncertainty with the additional equipment needed for the Degremont system.
- Degremont equipment condition could not be easily assessed, as it was in Texas (it was built several years ago).
- Uncertainty with the schedule, because of transport from Texas, as well as customs clearance requirements, all of which we would have little or no control over.
- The Zenon factory and support personnel were locally available in Ontario.
- The Zenon equipment could be viewed at will (and has been) for purposes of design.
- The Zenon unit was the only one that could be leased, which was considered appropriate for an interim solution.

It should be noted that notwithstanding the above selection, both conventional filtration and other suppliers of membrane filtration will be considered for the long term solution.

SHORT TERM SYSTEM RECOMMENDATIONS:

Based on all of the above, the short term recommendations are as follows:

Recommendation No. 1 – Installation of an Interim Filtration System:

Install a mobile Zenon ultrafiltration system - based on rapid delivery time, proven pathogen removal (ability to meet the ODWS), small footprint, and straightforward residuals management. (Note: this technology very likely far exceeds what is needed for this situation. It has been selected, however, due to its ability to meet ODWS and its availability for rapid deployment and installation.) This system would also require:

- temporary water tank (volume 45 m^3) to receive treated water from the membrane filtration unit. It is proposed that this tank also be utilized as a chlorine contact tank by fitting it with the means to mitigate short-circuiting;
- a relocated chlorine injection point (after membrane filtration so that dechlorination of the waste stream is not needed, but prior to the chlorine contact tank);
- duplex high lift pumps (one duty, one standby);
- improved chlorine residual monitoring (i.e. through sampling after the chlorine contact tank);
- a new electrical service; and
- a disposal system for the continuous reject stream

The proposed works are currently estimated to have a total cost of approximately $1,900,000 and an installation time of 8 – 10 weeks. The cost estimate is based on the purchase price of the Zenon unit. Alternatives for renting the equipment or lease-to-buy arrangements should also be investigated. Cost estimates and schedule will be refined as the preliminary design progresses, and with input from the contractor selected by OCWA to undertake the installation work.

Recommendation No. 2 – Well Upgrades:

It is recommended that the well upgrade program discussed above proceed, once the membrane filtration system is in place. Depending on the findings of each step of the well field improvement program, the total costs for this work could range from $450,000 to $650,000, including well drilling, casing, sealing, lining, supervision, consulting services and reporting.

Recommendation No. 3 – UV Pilot Testing:

As one alternative in the long term evaluation, it is recommended that pilot testing of UV disinfection commence once the well upgrades have been completed. This pilot testing project should have participants from equipment supplier(s), university research staff, microbiologists, as well as engineers. The objective of such a program would be to identify a possible long term solution utilizing UV and chlorine disinfection that would provide a high level of treatment, and to develop sufficient test data to demonstrate its effectiveness, both to the MOE and the residents of Walkerton. This program is expected to cost approximately $50,000 to $70,000 for the installation of equipment, as well as another $50,000 to $100,000 for the investigation (for a total cost of $100,000 to $170,000). Funding from the MOE, American Water Works Association Research

Foundation (AWWARF) and other funding agencies should be sought at this time to offset some of these costs. The results are expected to have far reaching effects across-- the entire province and beyond.

As of the date of issue of this report, preliminary design is already underway for Recommendation No. 1.

It should be noted that the Long Term Water Supply System Study will be considering other solutions that could be used to provide safe, reliable drinking water to Walkerton in a cost effective manner, for the longer period. This study will also consider as an option, the concept of converting the interim filtration system to a permanent installation.

Appendix A

Hydrogeological Recommendations

APPENDIX A – HYDROGEOLOGICAL RECOMMENDATIONS

To:	Ken Campbell, R.V. Anderson Assoc.
Copy:	Dan Brown, Golder Assoc.
From:	Tim Lotimer
Date:	September 28, 2000
Subject:	Walkerton Back Up Water Supply Options
Reference:	043 – 004

In accordance with Ken Campbell's request, I met with Ministry of the Environment hydrogeologists Theo Beukeboom and Jim Gehrels following the project team meeting on September 14 to discuss the September 11 draft work plan. Mr. Jim Richardson joined us during the latter part of the meeting. The key issues expressed by the MOE was to ensure that the work would not pose a risk to the reliability of the existing supply and that it would improve the security of the aquifer by reducing the potential for surface or shallow groundwater interaction with the major aquifer.

All of the five wells (Well 6 and 7 and the three test wells 1-82, 2-82 and 1-86) are open holes that could allow movement of water from the shallow groundwater system into the deeper parts of the aquifer. It is possible that a contaminant that finds its way into the upper parts of the well could move to the deeper parts of the aquifer via any of these wells. Thus a major goal of the work would be to eliminate any potential movement of water between the aquifers and the shallow groundwater system or the surface by the installation of seals between the various zones.

Abandoning the test wells and installing liners in the production wells could accomplish this. For similar reasons, it may be necessary to characterize the well integrity and potential of the domestic wells etc. within the capture zone of the production wells, to determine if they allow surface or shallow groundwater to move to deeper sections of the aquifer.

It was agreed that a stepwise approach to the work was desirable, with analysis, discussion and concurrence following each major activity. However, the urgency to improve the supply was recognized.

OBSERVATION WELL 1 – 82 (MOE 1405778)

This well had the highest specific capacity of the two observation wells and Well 6 when the wells were initially drilled. Furthermore, it is desirable to utilize this site for a new well as it is far away from the existing wells, thus there is minimal risk to the production wells from work at this location.

It is assumed that the annular space between the existing 150 mm casing and the larger hole drilled to enable installation of the casing was not grouted. It has 50 mm pipe cemented inside of 150 mm casing and because of this pipe testing of the well can not proceed nor could the well be

abandoned, if required or desired, in accordance with Reg 903 (which requires sealing the well between aquifers and the surface). The proposed work plan at this location is:

1. Using a diamond core bit, drill the annular space between the 50 mm pipe and the 150 mm casing to the depth of the pipe then remove the pipe to enable detailed testing of this well.
2. Deepen the test well about 10 metres to a total depth of 85 metres. The purpose being to determine if the major producing zones identified at Well 7 are present at this location.
3. Conduct geophysical and video logging of the test well to identify and correlate the hydrostratigraphic units with the other wells.
4. Conduct flow distribution profiling, packer testing and depth discrete water quality sampling to characterize the relative contribution of flow and water quality from each of the aquifer units and the interaction with the surface.
5. Discuss the results of the work with the project team.

With respect to the development of a short-term water supply, there are two likely outcomes of this work. First, it may show that this well had the better specific capacity, due to higher yielding shallow zones (such as the 19 metre major producing zone identified in Well 6). The decision in this case would be to assess if this is an acceptable water supply, from a water quality perspective. If the answer is yes, then the well may be converted to a production well.

The procedure would be to temporarily seal the uncased portion of the well (i.e. below 6 metres) with bentonite gravel, pull out the existing 150 mm casing, drill and install 300 mm casing to the top of the major producing zone, or to a minimum depth, based on the results of the testing. Cement grout the annular space between the 300 mm casing and the larger hole used to install the casing, develop the well to a condition to maximize the well yield and to enable stop/start operation of the well with minimal turbidity, conduct aquifer testing and apply for a Permit to Take Water.

On the other hand, if the work shows that the deeper water producing zones, found at Well 7 are present, then this well will likely be converted to a production well. The key difference from the first alternative being that casing could be cemented much deeper, tentatively to a depth of 40 to 45 metres, eliminating the potential vertical movement of shallow groundwater into the deeper parts of the aquifer system.

If the work shows that the deeper producing intervals are not present at this location and the project team prefers not to develop the shallower zone, then this well could be converted to a mulit-level monitoring well by installing 32 mm diameter PVC pipe and screens at up to three zones, installing silica sand packs around the screens and grouting between the screened intervals.

OBSERVATION WELL 2 – 82 (MOE # 1405779)

Assuming that an acceptable supply can be developed at the Observation Well 1 – 82 then this well will be converted to a multi-level monitoring well. The procedure would be to:

1. Using a diamond core bit, drill the annular space between the 50 mm pipe and the 150 mm casing to the depth of the pipe then remove the pipe to enable detailed testing of this well.
2. Deepen the test well about 10 metres to a total depth of 85 metres. The purpose being to determine if the major producing zones identified at Well 7 are present at this location.
3. Conduct geophysical and video logging of the test well to identify and correlate the hydrostratigraphic units with the other wells.
4. Install 32 mm diameter PVC pipe and screens at up to three zones. Install silica sand packs around the screens and grout the zones between the screens.

WELL 6

Assuming that an acceptable supply has been developed at Observation Well 1 – 82 there are two options for Well 6. The first is to rehabilitate the well in an attempt to improve the capacity, eliminate the turbidity and provide additional wellhead protection. Alternatively, if there is no need to retain the well it could be abandoned.

Well rehabilitation

If work is to proceed at Well 6, the investigation should include additional testing of the shallow (19.2 metre) producing zone to determine whether it should be sealed off by installing a liner to a greater depth, perhaps 30 metres. The sequence of events would be to first install a packer assembly to enable testing of the shallow zone to assess its connection with the nearby surface water. Then, to assess the production potential of the individual zones use the packers to pressure acidify three general zones consisting of the deeper zones (5,6 and 7), then the intermediate zones (3 and 4), then the shallow zone (2). Upon completion of the acidification and testing, the decision could then be made whether the installation of a liner to seal the shallow zone is prudent or necessary.

Well abandonment

If the well is to be abandoned, we suggest the following method:

1. Remove the lineshaft pump.
2. Install bentonite gravel from the bottom of the well up to 50 metres, then Portland Cement grout, to a depth of 35 metres, then bentonite gravel to the base of the well casing, then Portland Cement grout to surface.

DRILLING A NEW WELL AT A LOCATION NEAR WELL7

If the Observation Well 1 – 82 site is not found to be an acceptable site for well construction, then a limited exploration program about 100 metres from Well 7, towards Well 6 could be considered. At this distance there is little or no risk to damaging Well 7 from testing or production well construction.

The work plan would be to:

1. Drill and install temporary 150 mm casing to a depth of 20 metres. Drill and uncased pilot hole to a depth of 85 metres.
2. Conduct geophysical logging, flow distribution profiling, packer testing etc. to determine the aquifer characteristics and alternatives for well construction.
3. Temporarily fill in the well with bentonite gravel and remove the temporary 150 mm casing.
4. Enlarge the hole, install and grout 300 mm casing to a depth of 45 metres.
5. Deepen the hole to the required depth.
6. Conduct aquifer testing etc. and apply for a Permit to Take Water.

WELL 7 SITE

The final stage of the work plan, once the new back-up supply is developed, is to improve the security of Well 7 by installing a liner in the well and converting TW 1 – 86 to a multi-level monitoring well.

Well 7

The lineshaft pump will be removed from the well. A 300 mm diameter liner, installed to a depth of about 45 metres will be installed in the well, and the annular space between the liner and the existing well grouted with Portland Cement. A new well pump will be required, as the existing bowl assembly will not fit inside of the liner.

TW 1- 86 (MOE #?)

This well will be converted to a multi-level monitoring well by installing 32 mm diameter PVC pipe and screens at up to three zones, installing silica sand packs around the screens and grouting between the screened intervals.

Appendix B

Equipment Availability

APPENDIX B

EQUIPMENT AVAILABILITY
(as of September 12, 2000)

To date, faxes and phone calls have been sent to a series of equipment suppliers requesting information about filtration systems that could be provided on an emergency supply basis. The following is a list of contacts made:

- Culligan
- H2Flow
- Napier Reid
- Koch Membrane Systems
- Ecodyne
- Pall Water Processing
- US Filter/Memcor
- Zenon
- Aqua Technical Sales (re: Degremont/Aquasource)

Contacts have been made with the following supplier of UV Systems:

- Calgon
- Trojan
- Suntech
- Metcon (re: Capital Controls Ultradynamics UV systems)

In addition, contacts were made with a series of tank, pump and valve suppliers to identify delivery time and cost issues related to an interim installation.

Filtration Systems:

The following is a summary of potentially useful responses that have been received regarding filtration systems that could be provided in a relatively short time:

1. Degremont/Aquasource (contact- Brian Gage): Degremont sold 18 ultrafiltration units to the City of Del Rio, Texas within the last few years. As it turns out, they only require 16 units and may have 2 surplus. Each of these units would be a little larger than required for Walkerton (exact size not known). Approval would be required from municipal council and the Mayor is away this week, therefore not positive this is a go, however there is a high expectation that the City wants to get rid of these. If sale is approved, the unit could probably be shipped within a couple of weeks. There would be some missing components such a clean-in-place system that would need to be added to the system, and some upgrades, reprogramming, etc would likely be required. Also, the unit is designed for turbid surface waters, and includes some recirculation pumps that would probably not be required in Walkerton.

   Partial equipment delivery time 2-3 weeks, complete not sure.

Cost: purchase only, plus Aquasource commissioning, etc. about $1.1M, plus temporary storage tank, pumps, electrical, piping, and enclosure – say $0.3M – total $1.4M. Rental not available.

2. Napier Reid (contact Tim Otton): Tim had two suggestions. First, they could supply 14-4' diameter FRP pressure filters with full backwash etc., in about 3-4 weeks. A few weeks after that they could get a steel coagulation contact tank completed and delivered to the site. We both identified a concern, however, that treatability testing would be required to determine what type of chemical treatment would be required – possibly alum plus acid to reduce pH to allow coagulation to work properly.

   Equipment delivery time: 3-6 weeks.

   Cost: approximately $250,000 for equipment. Don't need storage or high lift pumps, but would require some piping, electrical and enclosure – say $200,000 – total $450,000. Rental not available.

3. Zenon (contact Scott Lenhardt): Zenon has a modular Zeeweed-based ultrafiltration system, sized at 6400 m^3/d under nominal flux conditions that is available now for shipping. This system is self-contained, but would require a water receiving tank and high lift pumping – similar to the Aquasource system above. The installation commissioning time could be 3-5 weeks under optimum conditions

   Delivery time: Total implementation could be 4-6 weeks.

   Cost: First 6 months of rental at $30,000/month, after that $25,000/month. (Purchase cost of Zenon Unit $1.1 to 1.2M.) Additional works required (storage tank, pumps, electrical, piping, and small enclosure for tank/pumps only (since Zenon unit has self-contained enclosure, and Zenon start-up services – say $200,000.

UV Systems:

Of the UV suppliers we contacted, only Trojan was able to provide good information to date. They have two pilot units available (one to be used as duty and one standby) that can be delivered two weeks after a meeting to discuss the application and after they test the water.

We have already recommended to OCWA to send samples for testing. We have figured out a method to install the piping within Well 7 Pumphouse, and that the power supply is adequate, but that a small 600 V/208 V transformer would be required (an off-the-shelf type unit).

Costs for the units as follows:

- freight, start-up, training, teardown $1,920
- rental $3,900 per month (not clear from information if this is for one or two units)

The potential schedule would be as follows:

- start installation design – Friday September 15/2000
- OCWA hires a M/E contractor to start work on September 22
- OCWA orders the Trojan equipment Sept 15
- Dwg & Line spec to Contractor Sep 22
- Dwg & Line spec to MOE for approval Sep 22
- Contractor readies piping/power by Sep 29
- Trojan units installed week of Oct 1
- Units tested two weeks
- potable water ready by Oct 12

Notes:

- all equipment and contractor sole sourced (no tendering)
- contractor must be available and found & PO issued by Sep 21
- Trojan must be sent water samples Sep 13
- MOE must approve preferable in one week, but not greater than 2 weeks
- Total installation cost (excluding unit rental) $50,000 - $60,000
- purchase price not known at this time

Conclusions:

In our estimation the Zenon filtration proposal represents the best approach if a filtration system is selected. We have not yet developed a detailed implementation schedule for such a system but believe that it could possibly be implemented in a 4-6 week period. The costs given above still are very rough, but give some idea of the order of magnitude for the implementation.

The Trojan UV alternative has been evaluated more deeply with the costs and time frame noted above having a little higher degree of accuracy, but still with some potential unknowns.

Appendix C

Summary Lab Data

WALKERTON
SUMMARY OF DAILY BACTERIOLOGICAL RESULTS
(total coliform/E.Coli)
From May 30 to September 10, 2000

Date	Well #6		Well #7	
	Raw	Treated	Raw	Treated
June 14	20/0			10/0
June 15			6/0	
June 17				2/0
June 18	>80/0			
June 26				>80/0
June 27				>80/0
July 4	6/0			
July 7	4/0			
July 8	2/0			
July 9		58/0	6/0	24/0
July 10	2/0			5/0
July 11	6/0	24/0		
July 13	5/0			1/0
July 15	8/0			
July 16	7/0			
July 20	4/0			
July 21	2/0			
July 24	6/0			
July 25	2/0			
July 28	2/0			
August 5				2/0
August 6	2/0			
August 7		4/0		
August 10		4/0		
August 15	2/0			
August 16	2/0			
August 17	2/0			
August 18			1/0	
August 21			1/0	4/0
August 24	8/0			
August 26	1/0			4/0
August 27			4/0	
August 28	>80/0*		1/0	
August 29	4/0			
August 30			2/0	
August 31	4/0			
Sept. 1	2/0			
Sept. 2			8/0	
Sept. 3	4/0			
Sept. 5	1/0			

* Actual Level was 983

WALKERTON WELL 7
SUMMARY OF MOE ANALYSES
August 23 to September 9, 2000

Date	TC	EC	HPC	Turbidity #7 TU	Turbidity #6 TU
August 23			30	< 0.01	0.05
August 24			210	< 0.01	< 0.01
August 25				0.1/0.05	0.1/0.05
August 26	4		10/120	< 0.01	< 0.01
August 27	4		60	< 0.01	0.05
August 28	1			0.05	0.15
August 29				< 0.01	0.05
August 30	2	1	10	0.60	12
August 31			10	0.50	14
September 1			20	0.20	5.3
September 2	8		130	0.45	7.3
September 3				0.60	11
September 4	NO DATA				
September 5			10	0.05	0.50
September 6			30	0.05	0.4
September 7				< 0.01	
September 8			2.6	< 0.01	
September 9			2.3	< 0.01	

Notes:

1. Figures are treated and/or raw. Two values separated by a slash indicate treated/raw.
2. TC is total coliform
   EC is E.Coli
   HPC is Heterotrophic Plate Count
3. Blank values in HPC column are <10
4. Blank values in TC and EC represents absence

APPENDIX H

RAINFALL SAMPLING REPORT

Memorandum September 21, 2000

To: Marc Ethier, Senior Operations Manager
Central/Western Area

From: Rick Turnbull, Compliance Advisor
Central/Western Area

Re: Walkerton Water - Rain Event Sampling September 14 - 16, 2000

Arrangements had been made with the OCWA Response Centre in Walkerton to call either Rick Turnbull or Garry Palmateer should a significant (>25 mm) rainfall event occur. These arrangements were made to permit the clear demonstration that Well # 7 was or was not being adversely affected by rainfall impacted surface waters.

This procedure was deemed prudent in light of previous work (daily distribution system sampling by OCWA) that has cast considerable suspicion on the impact that Well # 6 was exerting on the bacterial populations within the distribution system subsequent to rainfall events (July and August). In point of fact the serious deterioration of water quality in the distribution system after the August rainfall event along with the findings of significant numbers of total coliform bacteria in the raw water of Well # 6 convinced OCWA staff to valve off Well # 6 and to shut down its power to prevent further disruptions to the distribution system. Also, more intensive sampling on Well # 7 was deemed important since initial hydrogeological investigations around Well # 5 clearly revealed the significant and adverse impact of surface water on that well and more recent hydrogeological work around Well # 6 cast doubt on the trustworthiness of Well # 6's ability to continually produce microbial safe water.

No formal procedure was established on when to sample at Well # 7 or if samples from the distribution system should also be collected. However it was agreed that the samples were to consist of 2-litre volumes to permit high volume filtration analysis for coliforms and aerobic spore formers. Samples were collected in either 1 litre or 500 mL containers supplied by GAP EnviroMicrobial Services Incorporated (GAP). Upon completion of the sampling, the containers were to be returned to GAP for analysis. One- litre volumes were filtered for total coliform and background count analysis (as compared to the industry standard of 100 mL). For the aerobic spore formers a volume of 500 ml was filtered. The remaining 500 ml was retained in case follow-up investigative work was required.

On September 14, 2000 at approximately 19:00 hours, I received a phone call from the Centre notifying me that approximately 30 mm had been collected in each of the OCWA rain gauges (one gauge per well located in the vicinity of Well #5, Well #3, Well #6, and Well #7). Well # 7 was sampled at 22:17 on September 14, 2000 (the well was pumping). Rain gauge readings were noted as follows:

Well #	Rainfall Amount (mm)	Time
7	29.5	22:26
6	30.5	22:35
3	30.0	22:41
5	30.5	22:48

A second set of samples from Well # 7 (this time raw and treated) were collected at 00:17 on September 15, 2000 (well pump was still running). At the time the treated water turbidity and free chlorine residual on the continuous analyzers were 0.03 ntu's and 2.12 mg/L respectively. The next sampling occurred at 02:14 but only treated water could be collected since the well had recently shut off.

Well #7 was revisited at approximately 07:14 but no sampling was performed since the well was still not running. At approximately 08:00, OCWA operations staff arrived to conduct routine tests which involved turning on the well temporarily. Raw and treated water samples were collected at about 08:18. Treated turbidity and free chlorine residual were displayed on the continuous analyzers and recorded as 0.04 ntu's and 2.60 mg/L respectively.

Raw and treated water samples were collected at Well # 7 at approximately 10:50 and at about 13:53. The treated turbidities on both of these occasions were 0.03 ntu's. The free chlorine residual fluctuated slightly with a 2.01 mg/L on the earlier sample followed by a 2.10 mg/l on the latter sample. As before, the turbidities and free chlorine residuals were obtained from the continuous analyzers. Additional rain gauge measurements revealed additional accumulation through the morning and early afternoon of September 15, 2000 as follows:

Well #	Previous Rainfall Amount (mm)	Total Rainfall Amount (mm)	Time
7	29.5	42.0	13:47
6	30.5	47.5	14:10
3	30.0	not read	
5	30.5	48.5	13:35

On September 15, 2000, three high-volume distribution system samples were collected from the kitchen cold-water tap in the "Enquiry" building, from the men's room cold-water tap in the Walkerton Community Arena, and from the men's room cold-water tap (main floor) in the County building. For information and comparison purposes it was also decided to check the water quality of the water from Well # 5 which had received a chlorine dosage of 2.5 mg/L..

In all cases, aerators were removed and the sampling point flushed for about 5 minutes before samples were collected. The samples were submitted to GAP on September 15, 2000 and analysis was initiated early on Saturday morning (September 16). Results were verbally received Sunday (September 17) and passed on to Gord Eagles and Marc Ethier on September 18, 2000. As indicated by the results, the water quality of the raw and treated well water from Well # 7 and the distribution system samples were excellent. In my opinion we have clearly demonstrated that Well # 6 has been negatively impacting the water quality in the distribution system on its own and that based on the limited sampling conducted during this rainfall event we can better rely on Well # 7 for the time being.

An evaluation of OCWA samples collected from the 21 distribution system points and from the raw and treated water points at Well # 7 for the time period of September 15 to the 18 inclusive, reveals that only one sample had a total coliform count (2 colonies per

100 mL) out of a total of 90 samples. Background counts of zero and no *E. coli* counts were documented for the remainder of the samples as well. These results should be compared to the results subsequent to the rainfall events for July and August (not in my possession) to present further evidence of Well # 6's impact historically on the distribution system.

If you require any further assistance with this data or with other information that I could help with, please feel free to call me.

With regard to the GAP Laboratory data, I trust the following summary will suffice (I have also faxed the results to the Walkerton location; attention Gord Eagles):

Sample Location and Time	Total Coliform (per 1000 mL)	Background (per 1000 mL)	Total Aerobic Spore Formers (per 500 mL)
Raw # 7, 22:17 on Sept 14	0	0	0
Raw # 7, 00:17 on Sept 15	0	0	0
Trt. # 7, 00:19 on Sept 15	0	0	0
Trt. # 7, 02:19 on Sept 15	0	0	1
Raw # 7, 08:17 on Sept 15	0	0	0
Trt. # 7, 08:18 on Sept 15	0	0	0
Raw # 7, 10:50 on Sept 15	0	0	0
Trt. # 7, 10:51 on Sept 15	0	0	0
Arena, 11:06 on Sept 15	0	25	0
Trt. # 5, 11:42 on Sept 15	0	32	13
Enquiry, 12:05 on Sept 15	0	0	0
County, 13:22 on Sept 15	0	0	0
Raw # 7, 13:53 on Sept 15	0	0	0
Trt. # 7, 13:54 on Sept 15	0	0	0

End of Memorandum